

# כנס החברה הגאולוגית 2013 תקצירים

עורכים:  
מייקל לזר  
רלי וולד  
דורית סיון

עריכה גרפית: נוגה יוסלביץ  
אוניברסיטת חיפה

עכו 2013  
י"ט-כ"א סיון תשע"ג  
28.5.2013-30.5.2013



הוצאה לאור על ידי החברה הגאולוגית הישראלית

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## ג'ראלד מרדכי פרידמן

1921–2011



חבר כבוד של החברה הגאולוגית הישראלית, נולד בברלין בשנת 1921. ב-1938, בטרם סיים את לימודי התיכון, נמלט ללונדון ועם פרוץ המלחמה הושם בהסגר בגלל נתינותו הגרמנית. לאחר זמן שוחרר וסייע במאמץ המלחמתי ככבאי וכאופה, השלים את הבגרויות החסרות ועד תום המלחמה סיים בהצלחה את לימודי התואר הראשון בכימיה, ובגאולוגיה כחוג משני, באוניברסיטת לונדון. 50 שנה מאוחר יותר יחזור ללונדון לקבל תואר דוקטור כבוד של האוניברסיטה. ב-1946 היגר לארה"ב ועבד במקצועו

ככימאי בחברת תרופות וב-1949 חזר לחבוש את ספסל הלימודים באוניברסיטת קולומביה משם יצא כעבור 3 שנים עם התארים מוסמך ודוקטור בגאולוגיה. 12 השנים הבאות עיצבו את דרכו המדעית. הוא בחר לעסוק במחקר יישומי בתעשייה. תחילה הקים עם חברים חברה לפרוספקציה של אורניום בשילד הקנדי ומשזו לא הצליחה להתרומם, מסיבות משפטיות, שם פעמיו לחברת הנפט אמוקו בטולסה אוקלהומה שם קנה את עולמו.

את עיקר מרצו ריכז בחקר סביבות השקעה סדימנטריות: קלסטיות, קרבונטיות ואופוריטיות והיחסים ההדדיים בין הפציאסים במרחב, הן בממד הלטרלי והן בממד הורטיקלי, תוך קריצה לסביבות רצנטיות כמפתח להבנת העבר. בכך הלך ג'רי בדרכו של מושא הערצתו, וולתו, ותלמידיו גרבראו וטונוהופל במחצית הראשונה של המאה העשרים.

מצויד בניסיון מעשי רב ערך חזר ג'רי לאקדמיה. 20 שנה ב-RPI ועוד 20 בברוקלין קולג' CUNY, תוך שהוא שומר על קשר מתמיד עם התעשייה וזו מצידה גמלה לו בהערכה רבה.

ג'רי נודע כאספן הישגים: מעל ל-500 פרסומים וביניהם כאלה שהוכרו כטובים במיוחד; מעל ל-50 דוקטורנטים; 70 מסטרנטים; 16 פוסט-דוקטורנטים; שותף בארגון עשרות כנסים; עורך אגדי של JSP ועוד 3 עיתונים; אין ספור כיבודים ואפילו חגורה שחורה ו-30 שנות פעילות בג'ודו...

ד"ר פרידמן היה קודם כל מורה ומחנך. היתה לו נאמנות ומחויבות ללא תנאי לתלמידיו. עמד לשרותם ותמיד תמיד עם יחס של כבוד וללא שמץ התנשאות.

אלינו הגיע ב-1964. ספק לטעימה ספק לגישוש. בקורס שהעביר במחלקה השתתפו רבים מאלה שיעצבו בהמשך את המחקר הגאולוגי בישראל. באותם ימים קשרי המדע עם העולם הגדול לא היו מפותחים כל כך וג'רי הביא עמו משב רוח רענן ישר מהחזית. הקשר הלך והתחזק וג'רי חזר שוב ושוב; פעם למכון החדש למחקרי נפט וגאופיסיקה ופעם למכון הגאולוגי וכל גיחה כזאת הולידה מונוגרפיה כזו או אחרת, פרי שיתוף פעולה עם חוקר מקומי. ובין לבין, כאשר שהה בארה"ב הזמין אליו משתלם תורן וכך שהו אצלו בזה אחר זה מוברה, עמיאל, גבירצמן, אנוכי ויצחק לוי. ונזכיר

שניים נוספים מתלמידיו, אלי גביש ז"ל ולורי אורדן בוכבינדר ז"ל. אין ספק שליבו היה איתנו. ב-1978 פורסם ספרו רב המכר על עקרונות הסדימנטולוגיה, עליו שקד ביחד עם ג'ון סנדרס. מי שמעלעל בו אינו יכול שלא להבחין ביחס המיוחד לו זכו חברי הקהילה הגאולוגית הישראלית. לשיא הגיעה תרומתו הנדיבה למכון למדעי כדור הארץ באוניברסיטה העברית.

מכאן נשלח איחולי בריאות טובה לרעייה. את סו, האחות במקצועה, פגש ג'רי לפני 63 שנים, אך משנשא אותה את תפקידה הבלעדי כיד ימינו של ג'רי בכל דבר ועניין, קטן כגדול, ומלאה אותו באדיקות שאין לה שיעור ואין לה דוגמא. לזוג נולדו 5 בנות ולמצעד ההישגים, העקיפים במקרה זה, אפשר להוסיף 18 נכדים ו-23 נינים.

לפני 3 שנים ביקש ממני ג'רי לקחת אותו לסיור גיאולוגי בגלבו. הוא סיפר לי שבצפון מדינת ניו יורק ישנו אתר של עצים מאובנים מהפליאוזואיק שהתגלה במאה ה-19 וכונה "יער הגלבו" והוא ג'רי, שנושא ההיסטוריה של הגאולוגיה היה אחד מעיסוקיו, יש לו עניין לקרב את הציבור הגאולוגי האמריקאי למקור השם. נסענו לשדה, הוא דגם סלעים מהקנומן ועד האאוקן, בקפדנות ובדייקנות כאילו היה מדובר במאמר ל-NATURE וצילם כמובן בעליצות רבה שלטים של הקרן הקיימת המציינים באנגלית את "יער הגלבו". ההליכה היתה קשה לו מאוד והכתיבה לא פחות, אך הוא התעקש והמשיך. התלהב למראה השיש בחפציבה, ובמעין חרוד גמע בשקיקה את סיפור הוויכוח שהתנהל במקום בין פיקרד לביילי וויליס. הצענו לו לנוח, לאכול, לשתות קפה, לבקר בחפירות מגידו, אבל הוא בשלו – דבק במשימה. בצהריים החל לטפטף גשם והוא מתאמץ לרשום הערות בפנקס השדה; בקושי מילה או שתיים. הבטחתי שארשום עבורו בפנקס בתוך המכונת והוא נעתר בחוסר רצון. זה היה יום השדה האחרון של ג'רי בארץ ישראל ולי היה עצוב.

כתב – עמיחי סנה

## חגי רון 2012-1944



חגי רון איננו. אני עובר במסדרון של קומת הקרקע באגף הדרומי של המכון למדעי כדה"א ומציץ לכוון החדר בו ישב רכון על המחשב, אבל עכשיו הוא לא שם. אחר כך אני עובר ליד המעבדה הפלאומגנטית אותה הקים, וטיפח ובעיקר טיפח את העובדים בה אבל הוא לא שם. האם חגי באמת איננו? ואולי אני רק מדמה זאת והוא עכשיו מסתובב במדבר מואבי או נסע לעבוד עם ליסה בסקריפס ועוד מעט יחזור. ואולי סתם התחשק לו להישאר תקופה יותר ממושכת בכברי ולחזור ולנהל את ענייני המשק ואולי

הוא מסתובב בהרי הגליל ובודק שוב את כווני ההעתקים ואולי הוא קודח גלילי סלע למדידות פלאומגנטיות על מנת לחזור ולבחון את נושא סבוב הבלוקים בגליל ואולי הוא בחרמון עם יהודה רוכן על עורקי הקלציט ומודד כוונים, ואולי בכלל הוא ירד לים המלח לנחל פרצים ודוגם בקופסיות פלסטיק קטנות, סנטימטר אחרי סנטימטר את הסדימנט של תצורת ליסן, אולי סוף סוף ימצא את אנומליית המונו-לייק לאחר שכבר מצא וחקר עם שמוליק את אנומליית הלהשפם. ואם לא נחל פרצים אז בוודאי בעובדיה או בארק אל אחמר אוסף עם ארי דוגמאות חדשות לבחינה חוזרת של הכרונולוגיה הפלאומגנטית. ואם לא בבקעת הירדן אז אולי בדרום הרחוק במכרה תמנע אוסף סיגים מתקופת הברונזה-ברזל. ואולי בכלל הוא טס עכשיו עם מייק בערבות אוסטרליה. ואולי סתם הוא פותח שולחן באיזו מסעדה גלילית ומגלגל מעשיה מתולדות המכון למדעי כדה"א, או בית-העברה וכברי או מימי אסקונדו יולג' עם גדי ולאה ואמוץ בפאלו אלטו.

אבל אני עובר במסדרון וחגי איננו. וכל כך חסרות לי מילותיו הפשוטות שהיה אומר בחיך (קצת ציני) "נעמת לי" והיה אומר זאת לחבריו ולמוריו ותלמידיו. אלה גם היו המילים האחרונות ששמעתי ממנו באותו צהרי יום שישי מהביל בכברי על הדשא שלפני הבית. עם הבנות ושתייה קלה ופלחי מלון. וגם הוסיף אז מעין חיך של עידוד (כך לפחות אמרתי לישו). אבל אחר כך הוא נעלם ושמו נוסף לרשימה המתארכת של חברינו למקום שנקרא פעם המחלקה לגאולוגיה, חברינו שהיו בתחילת או בשיא כוחם היצירתי ופתאום נעלמו: שוקה בראון ורפי פרוינד וגדי ערן ואלי טננבאום ועכשיו חגי רון. האם הם נמוגו? האם חבריהם ותלמידיהם ייצקו תוכן נוסף או אחר לפועלם? ומהו בכלל מכלול הדברים המקיים את המקום שנקרא פעם המחלקה לגאולוגיה? הספרייה, סיכומי המחקרים, התזות, לוחות הזיכרון, דברי ההספד, הכנסים הזיכרונות האישיים ההולכים ודועכים עם השנים?

"נעמת לי" אמר חגי כאשר נפרדנו לשלום בצהרי יום השישי המהביל בקבוץ כברי ואז נסעתי הביתה. בדרך עברתי דרך כפר ערבי שבו חגי אהב לסעוד וחציתי את ארץ ישראל המערבית בכביש מהיר הכמעט קליפורני שהיה שומם והוביל אותי לדרך העולה מהשפלה לירושלים. חשבתי לרגע על הילדים הקטנים של קבוץ בית הערבה שעשו את דרכם כפליטים מצומת קליה מערבה בואכה

ירושלים ואל השפלה והצפון ושם בנו להם הוריהם מקום חדש שמשקיף לים אחר – למערב. תזכור, היה אומר לי חגי כשהיינו יורדים לים המלח. אני מכאן מבית הערבה.

אני עובר במסדרון של קומת הקרקע של האגף הדרומי של המכון למדעי כדה"א, המסדרון שפעם היה מנותק מקומת המבוא של המקום שפעם נקרא – המחלקה לגאולוגיה. חשבתי אולי הוא שם במעבדה הפלאומגנטית, אבל איש לא ענה כאשר דפקתי בדלת. חגי נעלם.

כתב – מוטי שטיין

חגי נולד כאשר הוריו נמנו על חברי קיבוץ בית הערבה שליד יריחו. לאחר מלחמת השחרור הם עברו לגליל והקימו את קיבוץ כברי בו חגי חי עד יומו האחרון. חגי היה גלילי, אהב את הגליל, הכיר כל פינת חמד שבו וכמובן את הגאולוגיה של הגליל לפרטיה. לכן, היה ברור כי עבודותיו לתארים מתקדמים יהיו קשורים לגליל.

עבודתו לתואר שני בהנחיית רפי פרוינד ז"ל ואיתן שש יבל"א חקרה את העתק פקיעין ואת ברקצית פקיעין הסמוכה להעתק. שאלת המחקר היתה האם ברקצית פקיעין התפתחה בגלל תנועה לאורך ההעתק או במנגנון אחר. הברקציה נמצאת בתצורת סכנין הבנוייה בדרך כלל מדולומיט אפור, מסיבי וסוכרי. הברקציה התפתחה רק במקומות בהם תצורת סכנין בנוייה מחילופין של סלע למינרי, לרוב בצבע בהיר או אדמדם, עם דולומיט אפור ומסיבי. חגי מצא כי בברקצית פקיעין החלקיקים בנויים תמיד מהסלע הלמינרי ואילו המטריקס והחומר המלכד מהסלע המסיבי האפור. גודל החלקיקים יכול להגיע עד מעל למטר. מחשופי הברקציה אינם מוגבלים לקרבת ההעתק אלא נמשכים עד למרחק של כקילומטר מההעתק. שכבות הברקציה עברו מעוות אשר הביא ליצירת קמטים, בודינים ואף שברים הפוכים. ברקציה טקטונית ורסק (gauge) נמצאו רק בסמיכות רבה, עד מטרים בודדים ממישור ההעתק. מישור העתק פקיעין הוא תת-אנכי וצידו המערבי הוא הירוד; לעתים הוא נוטה מעט מזרחה (הפוך) או מעט מערבה (נורמלי). כיום רוב סימני ההחלקה על ההעתק הם בכיוון הדיפ, אולם נמצאו גם סימני החלקה אופקיים. בזמן הווצרות הברקציה הדולומיט הלמינרי היה הסלע היותר קומפלטני ולכן החלקיקים זוויתיים בנויים ממנו, הסלע המהווה את הדולומיט האפור היה אז פחות קומפלטני ויכול היה לזרום בין החלקיקים. מתצפיות אלו הסיק חגי כי הברקציה נוצרה בזמן תהליכי הדיאגנזה המוקדמים של הסלע, ללא קשר לתנועה לאורך העתק פקיעין שהינו צעיר. ומכאן שניתן להשתמש בגודל ההסטות של ברקציית פקיעין (גיל קנומן) כמדד להסטת לאורך העתק פקיעין (קדום למיוקן), הסטה כוללת של כ-2,300 מטר.

העתק פקיעין עבר לפחות שני ארועי תנועה. האחד כולל הסטה אופקית שמאלית בשיעור של כ-2,300 מ' לפני המיוקן, והשני, פעל לאחר הווצרות מישור הגידוע המיוקני, כולל הסטה נורמלית המתבטאת בהווצרות גרבו פקיעין שבו סלעים מגיל סנון ממוקמים מול סלעים מגיל קנומן.

עבודתו של חגי לתואר שלישי החלה בעקבות השערותו של רפי פרוינד כי תבנית ההעתקים בגליל, הכוללת העתקים שמאליים בכיוון NNW וימניים בכיוון NE, מצביעה על האפשרות שהם

עברו רוטציה על ציר אנכי. חגי בדק השערה זו באמצעות שילוב של מדידות פליאומגנטיות של הבלוקים הגדולים בגליל עם מדידת כיוונים של מבנים קטנים וגדולים ומגמת ההסטה לאורכם. עבודתו של חגי, שהחלה בהנחיית רפי פרינד ז"ל ונמשכה בהנחיית עמוס נור וצבי גרפונקל יב"א, אישרה את ההשערה של רפי. בעקבות עבודה זו הפך חגי למומחה בקנה-מידה עולמי בכל הקשור לפליאומגנטיות, לשימוש בפליאומגנטיות ככלי לתיארוך ארועים ארכאולוגיים, ובמיוחד לכל הקשור ברוטציה של בלוקים.

חגי ועמוס נור הראו כי רוטציה מביאה לנעילה של העתקים וגורמת להוצרות העתקים חדשים אשר מתאימים לשדה המאמצים. זכורה השמחה שלהם כאשר רעידת אדמה בדרום קליפורניה הראתה על קיום העתק חדש, בכיוון שאותו הציעו, במקום כאלו שנעלו. בעבודה בחרמון חגי יחד עם עמוס נור ויהודה אייל הראו כי רוטציה בשיעור של כ-70 מעלות קשורה ברוטציה של הרבה בלוקים קטנים ולא של בלוקים גדולים מאוד.

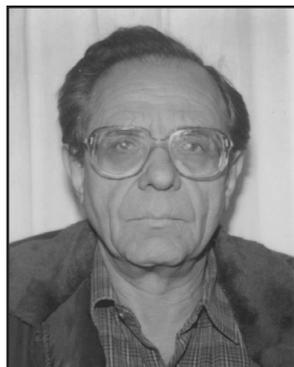
חגי הנחה תלמידים רבים ולכולם הוא דאג כאב הדואג לילדיו. הוא דרש מהם כי ידעו מה שאלת המחקר העומדת לפניהם, באילו שיטות יוכלו לפתור את שאלת המחקר, ובמיוחד דיוק במדידות, בעיבוד הנתונים והסקת המסקנות. לכן כל תלמידיו אהבו והעריכו אותו ביותר. חגי זכה בהרבה מענקי מחקר ומקרנות יוקרתיות כגון ISF, BSF ו-GIF וכן מקרנות אחרות. כל זאת בזכות כושרו להסביר את המחקר ונחיצותו למדע, וההכרה ביכולותיו המדעיות ובכושרו לסיים מחקרים בהצלחה. חגי גם שיתף פעולה עם מדענים בכירים בעולם כגון עמוס נור, מייק מק-וויליאמס, אטילה אידין וליסה טאוכס. חגי היה איש של אמת ולא היסס מחד למתוח ביקורת על עבודות מחקר או הצעות מחקר שלדעתו לא היו ראויות, ומאידך לשבח עבודות והצעות מחקר טובות. חגי היה חבר טוב ואיש רעים שתמיד היה נעים ומעניין להיות במחיצתו. הוא היה עמית מחקר שתמיד היה מרתק לעבוד עימו בזכות רעיונות חדשים שהיו באמתחתו. לא רבים זוכים לעבוד עם עמיתי מחקר כמוהו.

חגי האמין בקיבוץ עד יום מותו, ראה בו את ביתו, והיה פעיל במוסדותיו ככל שיכול היה. גם אם נסע לתקופות ארוכות לחו"ל תמיד שב אל ביתו ואל משפחתו בקיבוץ שבגליל. חגי וחדוה הקימו משפחה לתפארת וזכו לנחת מבנותיהם רותם, שירלי ושולמית מהחתנים ומהנכדים. אולם שניהם נפטרו מוקדם מידי מכדי לממש תוכניות רבות אותן רצו לבצע. חגי, ארבעים ושבע שנים של חברות, בצבא, בקיבוץ, ובמחקר גאולוגי נקטעו באיבחה אחת. שמחנו לראות כיצד אתה מתחיל להתאושש ולחזור לעצמך לאחר הסתלקותה של חדוה, אך הכורת לא הרפה.

כתב - ארי מטמון

יהי זכרך ברוך

## מנחם ראב 2013–1931



מנחם (מוני) ראב נולד בירושלים, אולם בגיל צעיר התחילה משפחתו את נדודיה במרכז הארץ, כשאחת מתחנותיה היתה במושבה רחובות. מאז נחשב מוני רחובותי.

את לימוד הגאולוגיה התחיל מוני בשנת 1952, כאשר המחלקה לגאולוגיה שכנה עדיין באבו תור (במקום הנמצא כיום במלון הר ציון), תחת קורת גג אחת עם המכון הגאולוגי. מחזור הלימודים שלו לא היה גדול, אולם נודע (בין השאר) בזכות השמות בעלי הצליל הדומה של חבריו – מוני, מושי, אורי, יוקי, מופי. במהלך שנותיו הראשונות במחלקה גילה מוני את חיבתו לפליאונטולוגיה, ותרגם במהרה חיבה זו לתחום המקצועי. תחילה כאסיסטנט (הלבוש תמיד חלוק לבן) של פרופסור אבנימלך, ובהמשך כחוקר עצמאי נלהב ומלהיב. מחקרו הראשון, במסגרת עבודת הגמר, עסק בהופעת הדגים המאובנים בתצורת דיר יאסיני (המוכרת כיום כחלק העליון, הלווחי, של תצורת כפר שאול). בהמשך העמיק בחקר קבוצות רבות של מאקרו פאונה, בעיקר מולוסקים, אולם גם מאוסטרקודים לא משך את ידיו. בכל אלה השאיר את חותמו היסודי ואת תרומתו בחקר הסטרטיגרפיה של האזור.

זמן מה לאחר הפרדת המכון הגאולוגי מהמחלקה לגאולוגיה באמצע שנות השישים, קיבל עליו מוני את תפקיד מנהל המחלקה לפליאונטולוגיה במכון, וכיהן בתפקידו כ-15 שנים. במהלך אותו זמן הוא נודע אמנם כמנהל קפדן בתחום המקצועי, אולם הוא היה רגיש לבעיותיהם של חברי המחלקה, וסייע להם בכל נושא ובכל לב. בנוסף לכך הוא עיצב את המחלקה בדרכו הייחודית, תוך כדי הפגנת כישורים מפליגים כגון, וכמגדל ציפורים, דגים וצבי מים.

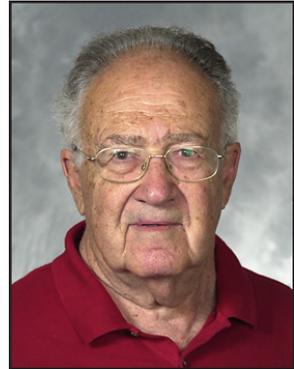
זמן מה לאחר סיום תפקידו, החל פרק חדש ותובעני בחייו המקצועיים של מוני. בהיותו חופשי מטרדות הניהול, הוא החל את מחקר הדוקטורט שלו בתחום הגאוכימי, בנושא האבפוריטים בבקעת הירדן – ים המלח. תחום זה היה זר לו לחלוטין, והוא חש (במילותיו שלו) כנטע זר. עם זאת, הוא לא ויתר, ובעקבות מאמץ ממושך ועקבי השתלט על החומר והגיע להישגים חדשים וחשובים בתחום הניסויי של איוד מי ים, ובשימוש בתוצאות הניסויים לניתוח מקורם ודרכי התפתחותם של האבפוריטים והתמלחות באזור. מוני היה בעל שליטה מושלמת בעברית, משורר לעת מצוא, ויוצר פורה של חידודי לשון. לפני כעשור הוא שילב את כישוריו המדעיים והלשוניים, ותרגם לעברית שני ספרי מדע פופולארי, האחד על הכחדת הדינוזאורים, והשני על התפתחות האדם. שניהם הפכו להיות רבי מכר.

מוני היה אדם רגיש, רב פנים וניגודים, בעל זיכרון מופלג, והומור מיוחד במינו, וכך גם נזכרהו.

יהא זכרו ברוך.

איתן שש

## יואל גת 2012-1926



חלוץ השימוש באיזוטופים למחקר מי תהום - שורות לזכרו.

יש אנשי מדע המסתגרים במגדל השן האקדמי ויוצאים נגד היישום המעשי של הידע שלהם בהצהרות על הצורך להגן על "המדע הטהור". בכך הם משתמטים מההכרח לעזור בפתרון בעיות קיומיות של החברה המפרנסת אותם. את הדוגמה ההפוכה לאנשי מדע אלו נתן פרופסור יואל גת ממכון ויצמן למדע, שהלך ביום שישי האחרון לעולמו. תרומתו, בעזרת מדע הכימיה בכלל והאיזוטופים בפרט במחקר המחזור ההידרולוגי וההקשר להימצאות מי תהום באזורים צחיחים, הם דוגמה לתרומה שהמדע עשוי לתרום לבעיות קיומיות באזורים צחיחים וחצי צחיחים.

על החשיבות של מדע האיזוטופים הסביבתיים, תחום התמחותו של יואל גת עמדנו לראשונה לאחר מלחמת ששת הימים. מהפרסומים המדעיים נודע לנו שקבוצת מדענים גרמנים מאוניברסיטת היידלברג בגרמניה בדקה את המים הארטזיים הנובעים בעויון מוסא ליד מפרץ סואץ בסיני ומצאה בעזרת בדיקות פחמן 14 שגילם הוא למעלה מעשרים אלף שנה. מהבדיקות הכימיות של המים שהם פרסמו התברר שמים אלו דומים לגיל המים שנמצאו בקידוחים לאורך עמק הערבה שמצאו מים בסלעי אבן החול הנובית. המשלחת ישראלית שיצאה לעויון מוסא לאחר כיבוש סיני דגמה את מי המעינות ואכן אנליזה של האיזוטופים הסביבתיים (חמצן 18 ומימן 2) של המים שהתבצעה על יד פרופ' יואל גת וצוותו במכון ויצמן הוכיחו שהמים בעויון מוסא והמים בערבה שייכים לאותה קבוצת מים ובני אותו גיל. מחקר משותף עם המרכז למשאבי מים, במכון לחקר המדבר בשדה בוקר הראה שמים אלו מאפיינים גשמים של סופות שבאות מדרום מערב בתקופת הקרח האחרונה. זאת כתוצאה מתזוזת חגורות האקלים דרומה כתוצאה מהרמה הברומטרית הקרה מעל אירופה. לעומת זאת רוב סופות הגשם העכשוויות באות מצפון מערב.

מים כאלו, בכמויות אדירות, נתגלו גם מתחת למדבר הסהרה על ידי חוקרים מארצות שונות. המסקנה הייתה שגם מתחת לחצי האי סיני והנגב מצויות כמויות מים אדירות שנקוו בשכבות של אבן החול הנובית בתקופת הקרח האחרונה, כאשר אירופה הייתה מכוסה בקרח ומדבר הסהרה ומדבריות המזרח התיכון היו גשומים יותר. הוכחה נוספת למסקנה זו התקבלה גם היא בעזרתו של יואל גת. היה זה לאחר שיקומו של קידוח נַחַל במרכז סיני, שנקדח תחילה לחיפוש נפט, אך כאשר נמצאו בו רק מים, הוא הותקן לשאיבת מים לשימוש הצבא המצרי. בזמן המלחמה פוצץ מתקן השאיבה. לאחר שהקידוח שוקם ונשאב התברר מהבדיקה האיזוטופית שההרכב של המים תואם את הרכב המים שנמצאו בשאר הקידוחים שחדרו לאבן החול הנובית, וכמובן גם למים של עויון מוסא. גם גיל המים מקידוח נחל הראה שמדובר במים עתיקים.

אך לא רק בישראל היו הידע והגישה של יואל גת לעזר רב אלא גם במחקר מי התהום בארצות אחרות כמו באירן. זה היה באמצע שנות השבעים, כאשר הוזמנו על ידי סוכנות האטום של האו"ם וממשלת אירן להדריך מדענים צעירים בשימוש באיזוטופים לצורך מחקרי המים. היחס הידידותי והרצון לעזור שהוא גילה כלפי תלמידיו, שאפיין את יחסו לעמיתיו ותלמידיו בכלל כבשו את לב מארחיו. כך גם היה בארצות העולם האחרות לשם הוזמנו לתרום מהידע הישראלי לפיתוח משאבי המים.

באמצע שנות השבעים נרתם יואל גת להקמתו של המרכז למחקרי מים, במסגרת המכון לחקר המדבר בשדה בוקר שהוקם על ידי אוניברסיטת בן גוריון בנגב. במסגרת המרכז התקיימו קורסים בינלאומיים שכללו גם הרצאות על השימוש באיזוטופים במחקר המים באזורים אלו בהשתתפות. בהמשך הנחה יואל גת את חוקרי המכון בתחומים המשותפים.

חסרונו של יואל גת, ידיעותיו וגישתו הבינתחומית יהיו חסרים במיוחד בעתיד. זאת נוכח ההשפעה השלילית שעלולה לגרום התחממות האקלים על משאבי המים באזורנו ואשר תביא לצורך בניצול מרבי של מי התהום ולפיתוח כלים חדשים למחקר ופיתוח.

לי אישית יחסר יואל גת הידיד והמומחה שהיה תמיד מוכן לבוא לעזרה, בעצה, בהרצאה לתלמידים ובהשתתפות במחקר.

כתב - אריה איסר

## שולמית גרוס 1923–2012



מקורה של תצורת חתרורים ("האזור המגוון"), החריגה בנוף הגאולוגי של מדינת ישראל, היה אניגמתי ונתון לויכוחים במשך למעלה ממאה שנה. בשל ייחודה, הוצעו הצעות שונות למנגנון יצירתה, חלקן משונות ולא סבירות. רק ב-1963 הוצע המנגנון המקובל כיום; בשנה זו הופיע מאמרם של יעקב בן-תור, שולמית גרוס וליזה הלר, בו תוארו לראשונה מינרלים היציבים בטמפרטורות גבוהות ולחצים נמוכים בסלעים אלה (ספוריט, גלניט, בראונמילריט). הוצע כי מקור החום ביצירת הסלעים היה "חימצון בפני השטח של חומר אורגני וסולפידים". מאותה שנה ובמשך כשני עשורים היה מחקר המינרלוגיה של סלעי חתרורים מרכז עניינה המדעי של שולמית (Gross 1970, 1977, 1980, 1984). שולמית זיהתה לא פחות מ-123 מינרלים בתצורה, ביניהם 9 שלא זהו קודם לכן בטבע, כולל חתורוריט ( $\text{Ca}_3(\text{SiO}_4)$ ), בראונמילריט ( $\text{Ca}_2(\text{Al,Fe})_2\text{O}_5$ ), באייריט ( $\text{Al}(\text{OH})_3$ ), ונגלשמדיטיט ( $\alpha\text{-Ca}_2(\text{SiO}_4)$ ), שולמית אף הגדירה שני מינרלים חדשים בעולם, ולהם קראה האחד על שם מורה-מורנו, בנתורייט -  $\text{Ca}_6(\text{Cr,Al})_2(\text{OH})_{12}(\text{SO}_4)_3 \cdot 26\text{H}_2\text{O}$ , והשני על שם ההר בו זוהה לראשונה - יעלימיט ( $\text{Ca}_4(\text{AlO}_2)_6\text{SO}_4$ ).

שולמית הפעילה במחקריה מגוון עצום של טכניקות אנליטיות: בדיקות מיקרוכימיות בהן היתה "קוסמת", הפרדות כימיות ופיזיקליות שונות, מיקרוסקופיה וכן XRD, DTA, TGA, SEM. במסגרת עבודתה היא אף הצליחה לשחזר במעבדה, בניסיונות חימום ממושכים, חלק ניכר ממינרלי החתרורים העיקריים ולקבוע את הטמפרטורה הנדרשת ואת תנאי יצירתם.

עבודתה של שולמית סוכמה במאמרים ובדוחות רבים, כאשר בולטין המכון הגאולוגי מ-1977 הוא המרכזי שבהם ובו מסוכמים עיקר ממצאיה על המינרלוגיה המורכבת והעשירה של תצורת חתרורים. כל העוסקים היום בסלעי החתרורים ניזונים מפרסומיה של שולמית והבולטין הנושא את שמה מצוי במדף הספרים של חוקרי החתרורים במקום מרכזי ומכובד.

שולמית גרוס (ליפשיץ) נולדה בגרודנו (אז פולין, היום בלרוס) ב-1923. למדה בבית הספר העברי "תרבות", והחלה בלימודי הנדסה באוניברסיטה של מינסק. עם הפלישה הנאצית לבלרוס ברחה שולמית לטשקנט שבאוזבקיסטאן שם התקבלה ללימודי גיאולוגיה. במסגרת לימודיה לתואר השני היא עסקה במינרלוגיה של אלוניטים ואף זיהתה שני מינרלים חדשים. לאחר סיום לימודיה עברה לאוניברסיטת מוסקבה, שם החלה במחקר לדוקטורט עם הקריסטלוגרף הרוסי הנודע ג.ב. בוקיי. היא סיימה את מחקרה אך לא הגישה אותו פן ימנע אישור הדוקטורט את יכולתה לעזוב את ברה"מ. אכן כאזרחית פולין לשעבר הורשתה שולמית לעזוב לורשה. בפולין הכירה את בעלה לעתיד- נתן גרוס, ועם שינוי שם משפחתה ומקצועה ל"פקידה" הורשתה לעלות ארצה.

רק ב-1958 חזרה שולמית למחקר מינרלוגי. ראשית במסגרת "מכון 4" של הוועדה לאנרגיה אטומית, שם עסקה בעיקר במחקר על מינרלי אורניום בפוספוריטים, לאחר מכן במכון הגאולוגי. במכון עסקה שולמית במגוון רחב של מחקרים מינרלוגיים וגאוכימיים, אולם עיקר מרצה וזמנה הוקדש, כאמור, למחקר המינרלוגיה המורכבת של תצורת חתרורים. את עבודתה המונומנטלית על תצורת חתרורים לא הגישה שולמית כעבודת דוקטורט, אף כי רבים ניסו לשכנעה כי ראוי שתעשה זאת. כאשר החליטה החברה הגיאולוגית על מתן "פרס רפי פרוינד" על מחקר גאולוגי מצטיין היתה שולמית גרוס כלת הפרס הראשונה שזכתה בו ב-1979.

שולמית היא מהדמויות הבודדות בעולם שזכו לכבוד כי שני מינרלים יקראו על שמה:

גרוסיט  $\text{CaAl}_4\text{O}_7$  שהוגדר ונקרא כך ב-1994 ע"י D. Weber ו-A. Bishoff.

ושולמיטיט שזוהה והוגדר כך ב-2011 ע"י Sharygin et al.

לשולמית שני ילדים - עליזה, חברת קיבוץ אשדות יעקב ויעקב במאי סרטים נודע.

כתב - יהושוע קולודני



## Brian H. Conway

### 1950-2012

Born 6<sup>th</sup> of March 1950, Passed away 15<sup>th</sup> November 2012. Brian had a wide field of interests in Palynology, Nannoplankton, Organic Thermal Maturation and Palynofacies analysis.

#### Academic background:

1972. B. Sc. Univ. London. (Geology)

1975. M. Sc. Univ. Sheffield (Micropalaeontology, Palynology).

1988. Ph. D. Univ. London (Jurassic Palynology of Israel and Organic Thermal Maturation).

#### Professional activities:

Immigrated to Israel on 13<sup>th</sup> September 1972;

April 1973 to September 1974, worked at the Geological Survey Israel;

1974-1975: England, Sheffield, worked as educational assistant;

May 1976 - September 1978: South Africa, as a palynologist for Southern Oil Exploration Corporation Ltd.;

October 1978 – 1988: Israel Geological Survey, as a researcher;

1988- 1989: Leave of absence in England, where he obtained his Ph-D from the University of London, followed by lecturing on Organic Maturation (M. Sc. Course) at Sheffield university,.

From 1989 until his retirement on 30<sup>th</sup> April 2010, Brian served as a researcher at the Geological Survey Israel, he got promoted to assistant professor in 1994.

From abstracts, reports and publications one recognizes three periods in the life of Brian as a scholar. The first decade, from 1978 until his Ph-D thesis in London (1988), Brian tackled the palyno-stratigraphy of the Jurassic system in Israel and its thermal maturity, both subjects that remained his strength during his entire career. In a second decade, he widened his horizon to englobe the younger Mesozoic and Cenozoic. In the third decade, the experienced researcher contributed enormously to oil exploration, in particular in the field of oil windows in the newly explored Mediterranean offshore boreholes

As a researcher:

In the GSI he was a meticulous and industrious scientist preparing all pollen samples using special extraction techniques that he developed himself. Working with him was tough but rewarding, as we remember, like preparing the Jurassic review paper for the Peri-Tethys project (1998), writing drilling reports together or studying some coalified wood in the petrified forest of the Ramon "crater" in the Negev. He was the ultimate authority in Jurassic bio-stratigraphy and when other tools would provide no reliable clues, he stood his point, even when other researchers did not accept his conclusions. But, after the years his determinations were found to be rock solid. Brian published 55 papers, technical reports and abstracts.

As a person:

Brian was born as the elder son of Sidney and Pat Conway (formerly Cohen). His loving and spirited family was living in Stratford, site of the recent Olympics rather than Shakespeare's, a fairly tough part of east London. He attended Stratford Grammar School where he did well academically. Stratford Grammar was unusual for its time, and for the area, in that it had several talented teachers who were trained to teach the earth sciences. This encouraged Brian's early interest in geology although he did not initially indicate that he would go to university later, like his boyhood friend Paul Smith. But Brian's excellent A-level grades gained him access to Queen Mary College, University of London. Paul was astounded and delighted to find him at the first day of classes. They experienced much field work and mapping together as part of their honors program in the Mendip Hills (Somerset). In his early years Brian loved to travel and in the summer of 1970, he and Paul hitch-hiked together through France, Switzerland and Italy making it as far as Rome.

In 1972, as a young tourist, Brian (Baruch) arrived in Israel. Looking for a job at the GSI, he was hired immediately. As his closest friends, we remember how during the 'Yom Kippur' war, Brian volunteered for a few weeks to help sustain border settlements, and was assigned to the Golan Heights. From 1974-1975 he went back to England to gain his Master's degree and from 1976 to 1978 he worked as a palynologist in South Africa. When he returned to Israel in September 1978, he joined the Paleontology division. While taking care of immigration procedures at the Ministry of the Interior, he fell in love with the officer who took care of him, Miriam, who soon became his beloved wife. Their three children, Inon, Ido, Rakefet are now successful and well educated adults.

Brian was a vivid, curious and inventive scholar. He contributed much to the oil exploration in Israel, the country to which he felt most attached. He was also generous with assistance to his

friends and colleagues. He worked very hard to build his home in Israel all by himself. In order to earn more money for his family he worked at night in a hotel as a sommelier. In spite of his face injury after a bicycle accident his spirit remained high and there was always a smile on his face. In his humble and quiet way he was full of dignity. This explains part of his personality, far from being a “snob” at all. His life has not been paved with many lucky events. At an early age, his beloved wife Miriam fell ill with a serious disease of the nervous system. While she was bedridden, Brian took care of her with love and care in an exemplary way until she died, 7 years ago. Soon after her death, Brian brought to Shimon’s office the large *Philodendron* that stood in Miriam’s room at home. Seven years later, during Shiva, Shimon told Brian’s children about the plant and, grateful, they promised to welcome the plant back into the family.

His three children were the light of his life, and, as a loving father, he maintained his family as a solid unit until the end. When he retired less than two years ago, Brian purchased an apartment in Netanya, closer to his children and grandchildren. Brian died of a heart attack on the 15<sup>th</sup> of November 2012.

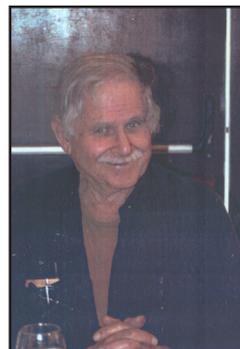
Brian was a good friend, gentle and caring, with lots of interesting conversations. He trod his own path and not everybody understood him. He never pursued honors, fame, or privileges. He will be remembered as a loving husband and father, a dear friend and reliable colleague, a careful and skillful researcher. We cherish and appreciate Brian as a scientist and as a “Mentsh”.

Be blessed His Memory.

יהא זכרו ברוך

Francis Hirsch, Shimon Ilani, Lydia Perelis-Grossowicz, Amnon Rosenfeld, Rimona Siman Tov,  
Paul Smith and Michael Dvorachek,

## אליהו וקשל 2012–1935



אליהו נולד ב 5 לינואר 1935 בתל אביב ונפטר במוצאי יום הכפורים 2012. את לימודיו בבית הספר העממי עשה ב'תל נורדאו' ואת לימודיו התיכוניים בבית הספר תיכון חדש. בצבא שרת בנח"ל ובמילואים היה רוב השנים בשריון בחטיבה 7 ואחרי מלחמת יום הכפורים ביחידה לאיתור נעדרים. לאחר שרותו הצבאי הצטרף לקיבוץ מעין ברוך ובשנת 1958 התחיל את לימודיו באוניברסיטה העברית בירושלים בחוג לגאולוגיה. נושא עבודת המסטר שלו היה 'הגיאולוגיה של אזור גזית'. לאחר סיום הלימודים עבד שנים אחדות בחברת 'תהל' בה התמחה בתחום ההידרו גאולוגיה. בשנת 1970 הצטרף למרכז לחקר מי תהום שהוקם באותו זמן באוניברסיטה העברית על ידי פרופ' פיקרד ופרופ' מנדל. מטרתו של המרכז היתה לבנות תשתית להוראת הידרו-גאולוגיה של מי תהום בעקב לתלמידי חו"ל מארצות מתפתחות ותכלית זו שמשה אבן דרך לאורך כל חייו המדעיים של אליהו עד מותו. בשנת 1978 השלים את עבודת הדוקטור על הנושא 'התפתחות הקרסט באקוויפר הקנומן – טורון בצפון ישראל' וכאשר שנה מאוחר יותר עבר המרכז למי תהום מירושלים לפקולטה לחקלאות ברחובות הוא הצטרף למחלקה לקרקע ומים כאיש סגל אקדמי.

אליהו מצא את הדרך לשלב את הוראת ההידרו-גאולוגיה, הן לתלמידי הפקולטה והן לתלמידי חו"ל, עם מחקר יישומי שהגיע לשיאו בשנות חייו האחרונות בהוצאת ספרו (יחד עם דוד זיתון) על Land subsidence analysis in urban areas (The Bangkok metropolitan area case study). הספר יצא בהוצאת שפרינגר לאחר מותו בינואר 2013.

בנוסף למעלותיו כמורה וכחוקר ניחן אליהו בכמות עצומה של טוב לב ורצון לעזור לזולת. הוא כמעט לא היה ממתין שיגיעו אליו אלא היה שואב אליו את המקרים שדרשו עזרה, אם בין תלמידיו ואם בין חבריו.

כולנו הוא יחסו.

אליהו הניח אחריו אשה, שלושה ילדים אסי, איתן ושלומית ושבעה נכדים.

כתב – אברהם סטרינסק

## גדליה גבירצמן ז"ל

1932–2013



מעגל חייו של גדליה החל וגם הסתיים בירושלים. את כל שמונים שנותיו עשה בעיר הזאת. גדליה היה בנם של, סגן ראש עיריית ירושלים משה גבירצמן ושל ד"ר נחמה גבירצמן, ואח לאסתר שפרעם. הוא סיים את בית הספר העממי בירושלים. את לימודי התיכון חילק בין הישיבה התיכונית בכפר הרואה (כתה ט'-י) ובית הספר "מעלה" בירושלים בו סיים את לימודיו התיכוניים ב-1951. הוא התגייס לנח"ל במסגרת גרעין שהשלים את קבוצת סעד. גדליה נשא את צמחה לבית וולנברג לאשה, חברות שהחלה בגיל 16 ונסתיימה לאחר ששים וארבע שנים של יחד אוהב, תומך ופורה. הם הולידו שבת גדול ונפלא: שלושה בנים ושתי בנות 28 נכדים ו-20 נינים. שבת של 70 נפש של יוצאי חלציו ובני זוגם, כמספר הנפשות במשפחת יעקב אבינו, ברדתם למצרים. זכות גדולה היא לאדם לראות בנים שלישיים וריבעים ורק מעטים זוכים בה.

חיי הקבוצה והעיסוק בחקלאות על גבול רצועת עזה לא יכלו לספק את סקרנותו ואת צמאון הדעת של גדליה והוא פנה ללימודי הגאולוגיה באוניברסיטה העברית. מקצוע שהיה בו לספק את תאוות הדעת שלו, לחקור את המופלא ממנו וליצור יש מאין. הגאולוג מתבונן בסלעים ממעוף הצפור בתצלום אוויר, בגובה העיניים במחשוף סלע בודד, בדוגמת יד, בזכוכית המגדלת ותחת המיקרוסקופ, ובהרכב הכימי והאיזוטופי של הגבישים. עבודת בלש, הצורף פרט לפרט עד שמצליח לשחזר את התמונה כולה. וזו היתה דרכו של גדליה – מן הגביש אל תצלום האויר ומדוגמת היד אל שחזור הפלאוגאוגרפיה של הארץ ושל האזור כולו.

גדליה עסק בתהליכי הדולומיטיזציה בהרי יהודה, בחקר הסטרוטיגרפיה והטקטוניקה של המזוזואיקון והטרציר, שחזור הפלאוגאוגרפיה בתקופות השונות, ושחזור הפלאואקלים בפלייסטוקן ובהולוקן. גדליה גילה את קו התמורה בקרטיקון ובטרציר ואף פרש אותו כשולי היבשת. אבל מעל הכל, עסק גדליה בנסיון עקבי ומעמיק לאתר את פוטנציאל הנפט של ישראל. גדליה יזם והיה בין מקימי המכון למחקרי נפט וגאופיזיקה, גוף ממשלתי יעודי שהוקם על ידי ממשלת ישראל בשנת 1964 לקדם את המחקר הבסיסי החיוני לחיפושי הנפט בארץ, על ידי שילוב המחקר הגאולוגי והגאופיזי. במסגרת זו עמד גדליה בראש מחלקת הנפט עד שנת 1982.

בתקופה זו זכיתי להתקבל למכון הגאולוגי, לעבוד במחיצתו ולהנות מידענותו, מגישתו המחקרית המעמיקה ומעל הכל מעידודו המתמיד בכל שלבי מחקרי. גדליה, שלא כמו מנהלי מחלקות אחרות במכון הגאולוגי באותה עת, ראה בהעמדת קבוצת חוקרים צעירים, בעלי ידע ומטיבציה יעודי מרכזי בדרך ניהול מחלקת הנפט. ולא בכדי הוביל גדליה את כל צוות הגאולוגים במחלקה לקבלת תוארי דוקטור, ולהפיכתם לדמויות פעילות ולעיתים מרכזיות בהווה הגאולוגית בארץ. ולא דבק בו שמץ גאווה והתנשאות, ולא קינא באיש מבין תלמידיו-עובדיו היותר מצליחים כדרך שקרה לרבים וטובים.

את כשוריו כמורה וכחוקר מימש גדליה בהמשך דרכו באוניברסיטת בר-אילן בה שימש כפרופסור לגאולוגיה החל משנת 1982 עד שפרש בעל כרחו כתוצאה מתאונת דרכים טרגית בעת שהותו בשנת שבתון בניו-זילנד ב-1999.

האסון בניו זילנד השאיר את גדליה שלם בגופו, אך הפגיעה בראשו גרמה לשנויים באישיותו וביכולותיו האינטלקטואליות וגזרה קץ למסלול רב ההשגים של מחקר והוראה שפסע בו גדליה. ואם לא די בכך, חלה גדליה גם בסרטן, שהפך את שלוש שנותיו האחרונות לקשות ומיוסרות. עם מותו נלקח מכולנו חבר קרוב, מורה, מדען ומנהיג רב פעלים והשגים.

יהי זכרו ברוך.

צ'רלי דרוקמן

## Geological implications for feasibility microseismic experiment at Mineral Beach, Dead Sea: Monitoring concealed collapses long before sinkhole occurrence

Abelson M.<sup>(1)</sup>, Aksinenko T.<sup>(2)</sup>, Pinsky V.<sup>(2)</sup> Yechieli Y.<sup>(1)</sup>

1. Geological survey of Israel
2. Geophysical institute of Israel

So far about 4,000 sinkholes have developed along the Dead Sea coast and the growth rate has reached more than 400 sinkholes per year. The hazardous shaft-like sinkholes occur at the alluvial fans, whereas the sinkholes at the mud flats are shallower and wider. The sinkholes at the alluvial fans also severely disturb human activity along the Dead Sea coast. Here we present indications that sinkholes at the alluvial fan can emerge to the surface long after (e.g., around 10-20 years) a considerable cavity has formed by dissolution of the salt layer. The mechanical competency of the fan sediments preserves concealed activity of underground collapse long before sinkhole occurrence. We conducted an experiment of microseismic monitoring in order to record such early collapse activity. Five geophones were planted within five boreholes located several hundred meters apart and with variable depths (between 10 to 25 m), around the sinkhole site of Mineral Beach. This site is a lineament of sinkholes, which first occurred at the mud flats and later propagated into the alluvial fan. During the monitoring period of 70 days (from 28.06.12 to 07.09.12), a total of 82 seismic events in the magnitude range of  $-3.6 \leq ML \leq 0.4$  were recorded (for more details see Aksinenko et al., this issue). Most of the events were located east of the sinkhole line on the alluvial fan rather than the mud flats. The location of the events may indicate concealed collapse activity east of the sinkhole line approaching the Mineral Beach resort area, in accordance with the sinkhole development at other parts of this sinkhole site. The depth range of these events is also in agreement with the depth of the salt layer inferred from seismic refraction and boreholes.

## Ground motion analysis and earthquake scenarios in the Zevulun valley basin

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Despite of the high probability of Israel being hit by moderate to large earthquakes, it is difficult to develop reliable damage and loss estimations mainly because the seismic activity in the region is low, and especially because ground motion amplification in basins is controversial. Traditionally, amplification of seismic ground motion in sedimentary basins is based on the average shear wave velocity of the upper 30 m of the soil column, the V-30 method. However, this widely used method ignores the deeper geological structure, which affects wave propagation in basins. The alternative of numeric simulations that model how seismic waves propagate through the entire sedimentary column (i.e., 1D, SHAKE-type, analysis) cannot be tested in Israel until a strong earthquake occurs; and thus the uncertainty about the proper way of estimating ground motion persists. The purpose of this study is to analyze, for the first time in Israel, the practical consequences of the two methods in terms of physical damage. For a case study, we chose the populated Zevulun Valley, which consists of a series of Graben-Horst-Graben, and where ground motion prediction based on the V-30 methods is different from ground motion prediction based on SHAKE analysis. The practical question posed here is what would be the difference in terms of damage and life loss. In the V-30 method the input motion, in the form of response acceleration spectrum, is multiplied by amplification factors according to the geotechnical units at depth of 30 meters below the surface, whereas in the SHAKE analysis the ground motion amplification at the surface is calculated based on the wave equation solution and input of elastic parameters of the entire sedimentary column in the basin. The shake maps are then used as input in the advanced HAZUS mr 2.1, 2012 loss estimation software. The HAZUS algorithms, which are based on input of spectral acceleration values, utilize default capacity and fragility curves of different buildings types, in order to estimate damage and loss. To examine the effect of ground motions on damage we simulated damages to buildings with uniform resistance to earthquakes. The preliminary results show excellent ability to give a practical method for estimating ground motion and damage in basins along the Israel area.

## The non-trivial ending of methanogenesis in the deep sediment of Lake Kinneret

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Methane production (methanogenesis) is the final process in the microbial respiration chain after other electron acceptors ( $O_2$ ,  $NO_3$ ,  $Mn(IV)$ ,  $Fe(II)$  and  $SO_4$ ) had been exhausted. In marine environments the dominant precursors for methanogenesis are  $CO_2$  and  $H_2$  (hydrogenotrophic methanogenesis) and in terrestrial environments the dominant precursor is acetate (acetoclastic methanogenesis). It is believed that methanogenesis is dependent on the availability of the substrate. The goal of this study was to investigate the non-trivial ending of methanogenesis in the deep sediments of Lake Kinneret, where substrate is still available. In situ profiles showed that in the deep sediment acetate and dissolved organic carbon concentrations increase. Incubation experiments showed acetate accumulation in the non-treated samples with time up to ~90 mM in the deep sediment, indicating that this substrate is not used, and that acetogenesis rather than methanogenesis dominates the deeper sediments. Addition of substrates (acetate; dimethyl sulfide (DMS);  $H_2/CO_2$  4:1 atmosphere) did not significantly enhance methanogenesis in the deep sediments within the first 3 weeks. After 100 days of incubation with DMS methane concentration increased in all depths and in the deep sediment there was a change in the color from brown to black as a result of iron sulfide mineral precipitation. The results indicate that methanogenesis is limited in the deep sediment of Lake Kinneret and that acetate or other electron donors are not limiting factors. The results give indication for the mechanism of methanogenesis inhibition. We therefore suggest 3 possible mechanisms to explain this phenomenon: (1) the dominant process is anaerobic methane oxidation coupled to iron reduction; (2) methanogens reduce  $Fe(III)$  and therefore produce methane to a smaller extent; (3) acetogenesis is the dominant mechanism in this depth acetogenesis and from an unknown reason this acetate is not available for methanogenesis.

## Three thousand years of Seemingly Time-Predictable Earthquakes, Tell Ateret

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Among various idealized recurrence models of large earthquakes, the “time-predictable” model has a straightforward mechanical interpretation, consistent with simple friction laws. The time interval between an earthquake and its predecessor on a fault that exhibits time-predictable behavior is proportional to the slip during the predecessor. The alternative “slip-predictable” model states that the slip during earthquake rupture is proportional to the preceding time interval. Verifying these models requires extended records of high precision data for both timing and amount of slip. The precision of paleoearthquake data can rarely confirm or rule out predictability, and recent papers argue for either time- or slip-predictable behavior. The Ateret site, on the trace of the Dead Sea fault at the Jordan Gorge segment, offers unique precision for determining space-time patterns. Five consecutive slip events, each associated with deformed and offset sets of walls, are correlated with historical earthquakes. Two of the correlations are based on detailed archaeological, historical, and numismatic evidence. The other three are tentative. The offsets of three of the events are determined with high precision; the other two are not as certain. Accepting all five correlations, the fault exhibits a striking time-predictable behavior, with a long term slip rate of 3 mm/yr. However, the 1759 ~0.5 m rupture predicts a subsequent rupture along the Jordan Gorge toward the end of the last century. We speculate that the 1837 earthquake on the Roum fault branch (~5 ka recurrence) has disrupted the otherwise time-predictable pattern.

## Localization of Shear in Fluid-Filled Gouge Zones: Insights from a Multi-Scaled Granular-Fluid Model

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The coupled mechanics of fluid-filled granular media controls the behavior of many natural systems such as saturated soils, fault gouge, and landslides. The grain motion and the fluid pressure influence each other: It is well established that when the fluid pressure rises, the shear resistance of fluid-filled granular systems decreases, and as a result catastrophic events such as soil liquefaction, earthquakes, and accelerating landslides may be triggered. Alternatively, when the pore pressure drops, the shear resistance of these systems increases. Despite the great importance of the coupled mechanics of grains-fluid systems, the basic physics that controls this coupling is far from understood. We developed a new multi-scaled model based on the discrete element method, coupled with a continuum model of fluid pressure, to explore this dynamical system. The model was shown recently to capture essential feedbacks between porosity changes arising from rearrangement of grains, and local pressure variations due to changing pore configurations. We report here new results from numerical experiments of a continuously shearing layer of circular two-dimensional grains, trapped between two parallel rough boundaries. The experiments use a fixed confining stress on the boundary walls, and a constant velocity applied to one of the boundaries, as if this system was the interior of a sliding geological fault filled with 'fault gouge'. In addition, we control the layer permeability and the drainage boundary conditions. This talk presents modeling results showing that the localization of shear (into a narrow shear band within the shearing layer) is strongly affected by the presence of fluids. While in dry granular layers there is no preferred position for the onset of localization, drained systems tend to localize shear on their boundary. We propose a scaling argument to describe the pressure deviations in a shear band, and use that to predict the allowable positions of shear localizations as a function of the fault and gouge properties.

## Seismic monitoring of the dynamics of sinkhole collapse at Mineral Beach, Dead Sea shore

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During the last 30 years thousands of sinkholes have appeared along the Dead Sea shores in both Israel and Jordan. The control of cavity evolution and its effect is thus a problem, which requires serious examination. Geophysical methods are widely used for sinkhole detection. They have allowed studying salt distribution and voids within the salt. In theory, when salt dissolution creates a cavity, the top stresses, fractures and falls can occur resulting in seismic impulses. The problem is to locate exactly in 3-dimensional space the position of the seismic impulse source, 'the hypocenter'. Microseismic techniques were applied to monitor the dynamics of sinkhole development in Mineral Beach, along the Dead Sea shore. To monitor micro-events the technology developed by the Institute of Mine Seismology (South Africa) was applied. The monitoring system includes the hardware and software products. The hardware is a micro-seismic array, which includes 5 short period sensors, which was installed into dedicated boreholes. The data of the downhole and refraction seismic surveys carried out in Mineral Beach showed that a velocity model in the study area can be presented by three velocity layers. We used average velocity, which was obtained by a trial and error method with the available constraints (depth of salt and location residual is below 5%). During the monitoring period (from 28.06.12 to 07.09.12), a total of 82 seismic events in the magnitude range of  $-3.6 \leq ML \leq 0.4$  were recorded. Most of the observed seismic signals had durations of 1.5 to 10 s. From all the detected events, eight were microearthquakes with a local magnitude range of  $-1.5 \leq ML \leq 0.4$ . The result showed the spatial and temporal grouping of Mineral Beach events in three clusters in a close proximity to the sinkholes at the alluvial fan of the Hatsatson Wadi.

## Hydrogeological and Environmental Analysis of Water Supply Wells Located in Wadi Ara, Ma'anit, & Karkur

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The National Water Company, Mekorot, performs a series of environmental surveys in order to identify potential pollution sources to the water supply wells. The subject work was conducted by Ecolog Engineering LTD, and included 12 water supply wells located in the Wadi Ara, Ma'anit, and Karkur regions of Israel. The investigated wells were: Blume 2, Wadi Ara 1, 2, 3, Karkur 36, 38, 145, 146 and Ma'anit 1, 2, 3, 4, 5 wells. The survey was conducted in the north-west Sharon region, located at the foothills of northern Samaria and within the upper catchment of the Hadera River. The wells utilize water from the Judean Group aquifer, built of limestone and dolomite with a number of intermediate units of chalk, clay and marl. The Judea Group outcrops east of the survey area, at Kemer Yron, and northern Samaria are the natural recharge areas of the aquifer. All of the surveyed wells utilize the upper sub aquifer (Bina and Sakhnin Formations), and most of them have a high water quality. Analysis of water quality over the past 25 years revealed isolated irregularities with no clear trend. Based on the evaluation of groundwater levels and the associated trends of groundwater flow directions, the Wadi Ara 2 and 3 wells feed-off a north-west groundwater flow component, from Kemer Yron and northern Samaria, while the other wells are fed by a flow component from the north, derived from the southern parts of the Yarkon Taninim basin. Wadi Ara wells are located close to the confinement line, however, the confining layer (Mt. scopus group) is located above the groundwater levels of the aquifer, therefore local hydrologic conditions are phreatic. Data from the Ma'anit and Karkur wells show confined conditions with the aquifer water levels significantly higher relative to the the top of the aquifer. Based on the subject survey potential anthropogenic pollution sources were determined according to the hydrogeological, physical and environmental conditions. The potential pollution risk to the water supply wells was determined to be high in areas adjacent to sewage infrastructures, and at hydrogeologically medium to high sensitive sites. It is important to note that according to the water quality analysis there is a noticeable improvement in the water quality of Wadi Ara 1 well, most probably as a result from improvements in the sewage infrastructure, and cessation of sewage flow to the Yron river in close proximity to the well. It is possible that the source of irregularities measured in previous years at groundwater samples (Turbidity and TOTB) from wells in the area, are a result of pollutants flushed from the surface (i.e., sewer) to the aquifer.

## Trace element composition of shales and dolostones from the Ardon formation, Ramon, Israel

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The shale–dolostone sequence of the Jurassic Ardon formation marks the first marine transgression and deposition after a ~15 m.y. long hiatus represented by the Mish'hor formation laterites. Shales and dolostones of the Ardon formation are enriched in trace elements compared to a global average shale composition (PAAS). The trace element signature of dolostones is dominated by the detrital component, because trace element contents of carbonates are negligible. Both rock types are LREE (La–Nd) enriched by a factor of 1.5. Shales are also HREE (Tb–Lu) enriched by a factor of 2–2.5 whereas Zr and Hf show an enrichment by a factor of 2.5–3 and are linearly correlated. In dolostones, however, MREE (Sm–Gd) are enriched by a factor of 2.5–2.7 and Y is also slightly enriched ( $Y/Ho \approx 1.1$ ). The cause for the enrichment is currently unknown. Shales from the Ardon formation are usually considered to be recycling of the underlying Mish'hor formation. On the one hand, enrichment and correlation of Zr and Hf suggest that zircon is concentrated in the shales. However, the amount is not sufficient to account for the elevated HREE contents and other heavy minerals could be responsible. On the other hand, laterites are commonly enriched in REE worldwide so it is possible that the shales represent an average value of enrichment that occurred in the precursor Mish'hor formation. The enrichment pattern of the detrital component of the dolostones is different, suggesting a different source for the detrital material. The MREE and Y enrichments are enigmatic. Sr isotope analysis of the carbonate fraction of one dolostone sample gives a  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of  $0.707442 \pm 0.000016$ . Assuming that the ratio has not changed since primary deposition, we are able to corroborate the age of the Ardon formation to Sinemurian, at ~195 Ma. This would also indicate that the dolomites of the Ardon formation formed penecontemporaneously to the deposition of the unit. The shale–dolostone sequence of the Ardon formation provides a promising direction for research on both provenance studies and trace element enrichment in sedimentary rocks.

## DRASTIC GIS Model Application for Groundwater Vulnerability Maps

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Friends of the Earth-Middle East's 'Protecting Groundwater' project provides 28 municipal authorities in Israel, Jordan, Palestinian Authority and Spain with technical and managerial tools and training in order to alleviate pollution of groundwater in their jurisdiction area. In this project, GIS-based groundwater-vulnerability maps were created for each municipal authority jurisdiction area (Jordan Valley, Hefer Valley, Beit Shean, Gilboa, Baka El-Gharbia, Mate Yehuda, Eshkol and Tamar). The groundwater vulnerability maps were uploaded to web-based information system that enables reporting, mapping and characterization of potential sources for groundwater pollution. The groundwater vulnerability maps assist in locating increased vulnerability zones where special attention is required in order to prevent groundwater pollution. Therefore these maps may be used as an instrument supporting decision makers, municipal advisors and municipal engineers in prevention and reduction of environmental risk factors. The DRASTIC GIS Model is based on a method developed by the EPA (EPA, 1987) and the National Water Well Association. It produces a relative-risk scale of potential groundwater vulnerability to pollution applicable to large areas (over 0.4 km<sup>2</sup>). This method employs numerical ranking system, which assigns relative weights to various hydrological parameters thus assisting in the evaluation of groundwater relative vulnerability to pollution. In this Model seven hydrogeological and physical parameters were taken into consideration: depth to water, (net)recharge, aquifer media, soil media, topography (ground surface slope), impact of vadose-zone media and the hydraulic conductivity of the aquifer. Raster maps were created for each parameter and every map cell (50 m<sup>2</sup>) has been given a relative DRASTIC index number describing its groundwater vulnerability according to hydrological, geological, climatological and physical databases (1 for low vulnerability and 10 for high vulnerability). The groundwater vulnerability map was created by programming a specific Model Builder application in ARC-GIS 10 environment. Every hydrological parameter was characterized by 1-5 weight, proportional to its importance and influence. For each map-cell the DRASTIC index has been multiplied by the weight, and all hydrological parameters were combined to create a map in which the groundwater vulnerability is manifested in five vulnerability grades: very high, high, moderate, low and very low. This novel model is applicable to large areas and all types of aquifers, based on analysis of local geological and hydrological conditions. Therefore, this model can be used as a modeling approach for any project in regional and national scale in which groundwater vulnerability assessment is required.

## Benthic Foraminifera as Indicators for Sub-Marine Slide Events in the Northern Gulf of Eilat/Aqaba

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The Northern Gulf of Eilat/Aqaba, located in the southern end of the Dead Sea fault, has high tectonic hazardous potential. The frequent seismic activity in this region, related to the four main faults that dissect the gulf head, seems to trigger sediment collapse. We hypothesize that earthquakes leave evidence as underwater mass flow sediment units (turbidites). In this study displaced sediments were identified by using the characteristics of marine microfossil assemblages and their taphonomy (state of shell preservation). Thus, the specific aims of this study are: (1) to establish the reliability of symbiont bearing larger benthic foraminifera (LBF) as a proxy for paleo-seismicity based on their known habitats and their anomalous occurrence in displaced sediment layers in the deep sea bed; (2) to link the occurrence of displaced LBF fossil assemblages and the timing of past earthquakes in the area; (3) to establish the connection between the physical properties of the fossil assemblages and the intensities and energy involved in events triggering the sediments displacement. The research is based on Holocene and modern sedimentary records extracted from the basin floor (100-700m water depth). One of the studied cores was taken from the lower part of a main canyon at 532m and the second core from the upper western slope at 316m. Foraminifera shells  $>150\mu\text{m}$  are hand-picked from above, within and below the disturbed units using a stereo-microscope. The microfaunal and taphonomic results were compared to the grain size analysis results of the two studied cores (Kanari et al., 2012). The disturbed units are characterized by coarse grain size and show generally higher numerical abundance of LBF and poorer preservation compared to typical deep sea fine pelagic sediments. Two LBF species, namely *Assilina ammonoides* and *Amphistegina papillosa*,  $>1\text{mm}$  appear in the disturbed sediments with the former comprising up to 70% and the later up to 25% of the total LBF assemblage respectively. This, unlike sediments between the disturbed units where these species hardly appear. Moreover, the depth range of the living population is restricted to shallow water, between  $\sim 40$  and  $\sim 120\text{m}$  in accordance with light requirements of their symbionts. The occurrence of LBF  $>1\text{mm}$  indicates that high energy is involved in the displacement. The disturbed units contain up to 40% of yellow LBF, as opposed to 0% in non-disturbed units and unlike living specimens that are of whitish color. Yellowish color is known to be associated with increasing burial time/depth. These results indicate the reliability of LBF as

paleo-seismicity proxy and suggest further lab work and data analysis to yield more advanced results and conclusions that will shed light on turbidite dynamics, relative magnitudes and recurrence intervals of past mass-flow events and possible correlation with known earthquakes.

## Benthic foraminifera turnover in the Late Cretaceous high productivity sequence of the southern Tethys, Negev, Israel

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The Late Cretaceous marine succession in Southern Israel is composed of a variety of rock-types including chalk, phosphorite, chert, porcelanite, organic rich carbonate and marl. These rocks are indicative of the upwelling regime that prevailed in this region and characterized by high surface water productivity and sea floor oxygen deficiency. A most prominent lithological transition occurs from the phosphate-silica bearing rocks of the Phosphate Mbr, Mishash Fm to the monotonous organic rich carbonate rocks of the Oil Shale Mbr (OSM), Ghareb Fm. In order to explain this transition we used benthic foraminifera, an important component of this succession, as sensitive indicators of paleoceanographic conditions including possible changes in the paleobathymetry.

Two late Campanian-Early Maastrichtian sections in the Negev, southern Israel were investigated in this study: The Saraf core located northwest of the Zin Valley synclinal axis and the exposed sequence at the PAMA quarry located at Mishor Rothem. The sharp lithological transition between the Phosphate Mbr and the OSM is accompanied by a turnover from buliminid to rotaliid dominated benthic foraminiferal assemblages. The Phosphate Mbr is characterized by extremely low species richness with *Praebulimina prolixa* dominating its lower part and *Neobulimina canadensis* its middle and upper parts, which are both indicative to anoxic bottom water condition. A sharp increase in species richness and first appearances (FAs) of many benthic species occur at the base of the OSM. These include the FAs of *Gyroidinoides*, *Gavelinella*, *Oridorsalis*, *Bolivinooides*, *Alabama*, *Osangularia*, *Sliteria varsoviensis* and *Nuttallides truempyi*, taxa known to inhabit upper bathyal water depths., A distinct acme event of *Elhasaella alanwoodi* occurs slightly above the base of the OSM, reflecting opportunistic colonization possibility in response to a change in food source or water depth. The main turnover in benthic foraminifera assemblages at the Phosphate-OSM transition was previously attributed to a change from anoxic to dysoxic-oxic conditions and a shift in the location of the active center of the upwelling system further southeastward, leaving the Negev area still productive though of more distal position. Recent geochemical studies have shown that the aeration have not changed dramatically between these two time intervals and the sea floor was still highly O<sub>2</sub> depleted during the deposition of the OSM. An alternative explanation

suggested here, attributes the distinct changes in the benthic foraminiferal assemblage composition to a regional change in paleodepth from shelf environment (0-200) at the Phosphate Mbr to upper bathyal (200-600) in the OSM. A shift in primary producers from diatom dominating phytoplankton during the Phosphate Mbr to calcareous nannoplankton dominating phytoplankton during the OSM might be another factor that triggered the assemblage composition turnover.

## Geomorphology of the submarine Akhziv canyon and its relationship to the Northern Galilee fluvial system

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The northern continental shelf of Israel is relatively steep and incised by submarine canyons. The Akhziv canyon is the largest, most developed and southernmost in a series of canyons off-shore Lebanon. The canyon head is located 3 km off the northwestern Galilee coast. It begins at a water depth of 40 m, reaching a final depth of 1,200 m. The aim of this study is 1) to understand the processes responsible for the canyon's morphology and its connection to the western Galilee fluvial system; 2) to understand its relation with the region's fault system which transverses the continental shelf; and 3) to investigate the mechanisms of sediment transport and accumulation in the continental shelf and inside the canyon. Geomorphologic mapping and morphometric analysis of the canyon and the adjacent shelf was carried out based on the high-resolution bathymetric map (the National Bathymetry Project). Gaps in the submarine aeolian calcarenite ridge on the shallow shelf indicate the westward continuation of the fluvial streams during a period of low sea level. Alluvial fans mapped at 40 m water depth testify to the transport of sediments from land to the continental shelf toward the canyon head. The upper part of the Akhziv canyon consists of two main V-shaped channels. The channels meet at a depth of 700 m, producing a U-shaped main channel. The orientation of the channels suggests a relation to the local fault system. Shallow high-resolution seismic lines (Sparker) were carried out along the continental shelf and canyon head in order to reveal the sub-surface structure. The seismic interpretation indicates the presence of channel incisions at depths of 10-15 m beneath the seafloor. The channels are filled with young sediments which represent phases of deposition and erosion along the continental shelf. The geomorphological map and the results obtained from sub-surface seismic interpretation present the relation between the Akhziv sub-marine canyon and the terrestrial system of the western Galilee. Further efforts to date the sediments which were sampled along the main axis of the canyon will reveal their connection to the glacial-interglacial cycles which have affected the eastern Mediterranean continental shelf.

## Mapping of the subsurface in and around Be'er Sheva using seismological survey

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The Be'er-Sheva area was investigated using the horizontal-to-vertical spectral ratio of ambient noise in 166 measurement points. The H/V resonance frequencies were observed with one and two peaks. The first resonance frequency is associated with the top of Judea Gr. The second resonance frequency is associated with top of Neogene and Paleogene, covered by the Quaternary sediments. The S-wave velocity model for lithological units represented in the area was developed using ambient noise measurements, borehole data and surface geology. It was demonstrated that velocities of marl-chalk sediments of Neogene and Paleogene have very similar values. The map of the average shear-wave velocity for upper 30 meters (VS,30) was compiled. Four schematic geological cross-sections were constructed, based on H/V ratios analysis and geological data. The depth to the main reflector was estimated and the appropriate map was constructed, the map of the reflector surface, calculated from the sea level, was also built. Several faults were defined and traced across the area. The maps and cross-sections showed new local geological structures that were not identified in the structural map of top Judea (Fleischer and Gafso, 2003). This study provided seismic hazard microzonation of the investigated area, resulting in the microzoning map of the Be'er-Sheva area. Appropriate generalized models are proposed for each zone. The characteristic acceleration response spectra were computed using SEEH procedure.

## The use of P-wave spectra in the determination of earthquake source parameters in Israel

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The first time in Israel that an attempt is made to use the first few seconds of P-waves to determine dynamic earthquake source parameters while adhering to the well-established Brune's seismic source model. The study is based on 1240 digital records from 93 local and regional earthquakes in the magnitude range 2.7-5.6, occurring during 1995-2012 within 8 km to 550 km from stations of the Israel Seismic Network (ISN). It has been observed that both the low frequency displacement amplitude and the corner frequency are distance depended, i.e.,  $D=R*0.0042R$  and  $f_0=f'_0*0.00043R$ , respectively. These distance correction parameters were used to determine the displacement spectrum at the source, the seismic moment,  $M_0$ , moment magnitude,  $M_w$ , source radius,  $r_0$ , and stress drop,  $\Delta\sigma$  for each analyzed earthquake. The study reveals an anomaly regarding earthquakes that occur in the Gulf of Aqaba and recorded at distances great than 150 km, which are not yet resolved. The seismic moments of the analyzed earthquakes are between  $1.06*10^{13}$  and  $1.25*10^{17}$  Nm, corresponding to moment magnitudes- 2.6-5.3, with corner frequencies- 1.0-5.6Hz and stress drop between 10-1MPa and 39MPa. It is observed that stress drop increases with increasing seismic moment and possibly approaches a maximum level of about 40MPa. Comparing the source parameters estimated from P-waves with those obtained by Hofstetter and Ataev (2011) from spectra of S-waves shows that the values are practically the same. The empirical correlations between source parameters and the duration magnitudes are in agreement with those obtained previously from the analysis of S-waves by Shapira and Hofstetter (1993), Hofstetter (2003), Hofstetter et al. (2008) and Hofstetter and Ataev (2011) for events along the Dead Sea Fault and the Eastern Mediterranean region. This study confirms that spectral analysis of the first few seconds of the arriving P-waves to the ISN stations can be used to reliably determine the earthquake source parameters of local and regional earthquakes, yet, with the exception of earthquakes in the Gulf of Aqaba.

## The rule of desert floods on the evolution of sinkhole fields in the Dead Sea coastal plain

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The formation of sinkholes along the Dead Sea has been traditionally explained by the dissolution of halite in the sub-surface resulting from low salinity groundwater that reach deeper sub-surface layers as the lake level drops. In this model, the influence of surface water on the process was totally neglected. However, during the last years, complex relations between sinkhole formation and surface floods were gradually documented. Several sinkhole fields are monitored in the Ze'elim fan, the largest fan developed in the Dead Sea western coast. Since 2005, field observations and repeated LiDAR scans indicate that during floods, large quantities of surface water percolated into sinkholes that serve as conduits to the sub-surface. This was rapidly followed by the development of new sinkholes and led to the integration of discrete sinkholes into large depressions. This process has a positive feed-back mechanism: The water storage within the depression is giving way to a new phase of sinkhole development in increasing rates, leading to increases in the storage capacity. In addition, the growing depression facilitates the development of large gullies that migrate upstream, channeling more flood water toward it. In the eastern sector of the fan, the development of the rapidly growing depression decays the old drainage pattern running toward the Dead Sea, resulting in its abandonment. Two large sinkhole fields were developed in the eastern mudflat of the Ze'elim fan: 1. The Central-Western field. In 2005, this field was composed of few discrete sinkholes. After 7 years (2012), this sinkhole field has developed to a large area of more than 50,000 m<sup>2</sup> demonstrating a total volume growth of 400 folds. After a flood in spring 2012, we observed that the flooded depression, holding 60.00 m<sup>3</sup> of fresh water, percolated to the subsurface within 24 hours through a discreet sinkhole, emphasizing the ability of the sub-surface to deliver this large volume. This was rapidly accompanied by large developments of new sinkholes along the subsurface conduits leading eastward (N70E) toward the lake. 2. The Southern sinkhole field was rapidly developed in an almost linear pattern (N120-130E) immediately after a sudden flood recorded in spring 2012. As an outcome of the study, we developed a new model for sinkhole development based on a two stage mechanism. The first stage is completely controlled by sub-surface dissolution of halite by sub-surface water. This process is well known and widely described in the literature. The second stage is formed due to the gradual trapping of surface water within the developing sinkhole field that formed a broad

depression in the surface. The large amount of fresh water injected to the sub-surface promotes the rapid growth of the sinkholes field and leads to the formation of large conduits in the sub-surface.

## Thermally vs. seismically induced block displacements in Masada rock slopes

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Annual temperature fluctuations are responsible for generating irreversible displacements of removable rock blocks that are separated from the rock mass by the intersections of pre-existing discontinuities. A new mechanism, referred to here as “ratchet” model, is proposed to explain how cyclic thermal oscillations induce intermittent expansion and contraction of the tension crack, thus causing seasonal translations of rock blocks. New evidence for thermally induced block displacements is presented here using both climate and displacement data from a carefully monitored rock block in the West face of the Masada Mountain, a UNESCO World Heritage site, along with re-visited and re-analyzed monitoring data from the East face of mountain. The monitored deformation is explained here in terms of a weather-induced wedging failure that essentially operates as a “ratchet” mechanism involving the rock mass, tension crack, sliding block, and sliding surface. We test the model on a distinct block in the East slope of the mountain exhibiting a tension crack opening of 200 mm. Based on the assumed seismicity of the region and the known topographic site effect, along with the laboratory measured frictional resistance and shear stiffness of the sliding interface, we subject the mapped geometry of the block in the East face to simulated cycles of earthquake vibrations utilizing the numerical DDA method. We find that for a time window of 5,000 years, the observed 200 mm displacement of the East slope block is more likely to have been thermally, rather than seismically, controlled. The result implies that in climatic regions where the temperature amplitude over a seasonal cycle is sufficiently high, thermally induced displacements play an important role in rock slope erosion.

## Tectonic movements and sea-level changes from coral reefs along the Gulf of Aqaba

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Elevated or drowned coral reefs comprise geological archives for past sea level changes and tectonic movements in coastal areas, because they represent relative sea level (MSL) and allow accurate dating by radiocarbon and uranium-series methods. At least two major fossil coral reef terraces have been recognized along the eastern shores of the Gulf of Aqaba. The terraces, formed during the last interglacial period and the mid-Holocene, are elevated above the modern mean sea level. Reef facies are reconstructed and mapped in detail, and formation ages are determined radiometrically. The data are used for resolving local tectonic activity and sea level history. The last interglacial terrace shows  $0.09 \pm 0.01$  mm/yr uplift rate (assuming that sea level stood at  $\sim +6$  m above MSL) whereas the  $\sim 1$ - $2$  m (above MSL) mid-Holocene reef shows negligible movement. Coral reefs of similar mid-Holocene ages and elevation were documented and dated from other shores along the GOA. The apparent disparity between the rates suggests a long seismic cycle, with the next seismic event expected to raise the shores by  $\sim 5$  m. Alternatively, the average rate of uplift has declined since the Pleistocene.

## Neolithic voyages to Cyprus: Possible routes and mechanisms

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Recent archaeological evidence from Cyprus shows that humans first arrived at the island at around 12,000 calibrated years BP. Visits to Cyprus intensified and resulted in settlement on the island during the Pre-Pottery Neolithic A beginning around 11,000 cal BP. Later occupations of the Cypro Pre Pottery Neolithic B from around 10,500 to 9,000 cal BP are more numerous and testify to intensive connections with the Levantine mainland, expressed by the importation of both wild and domesticated plants and animals. As Cyprus has always been an island in these periods and earlier, it could have been reached only by seafaring. The routes possible to sail from the Levantine mainland to Cyprus were examined, in order to better understand the relationship between the island and mainland during these periods. The factors that were studied were: options of available watercraft; sea level, conditions and currents; navigation skills; sailing routes; and mainly prevailing winds in the various seasons of the year, and during the parts of the day and night. It is suggested that the best (and almost only) sailing route from the Levant to Cyprus by Neolithic navigators was from southern Turkey to Cyprus. They could have crossed this distance between April and October. A passage westward or northwestward from the Levantine coast to the southern coast of Cyprus cannot totally be ruled out, although with considerable less chances. Their return trip was from the east or southeast of Cyprus to the Levant coast, thus creating a counter-clockwise route, which enabled the permanent human settlement on the island.

## Distribution, concentration, and transport process of Hg in sediments offshore Haifa, Israel

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Haifa Bay region is affected by heavy industrial discharges introducing heavy metals. Mercury (Hg) levels in shallow water sediments and biota, which are monitored by the Israel Oceanographic and Limnological Research Institute as part of the Israel's National Monitoring Program, show elevated levels compared to the rest of the coast and above eastern Mediterranean background levels. Though Haifa Bay is considered a terminal basin for sediments transported along the south eastern Mediterranean, it is possible that contaminated sediments are eroding and further transported, carrying pollution to the north and deep continental shelf. Two main point sources of Hg pollution were found in Haifa Bay: (1) a chlor-alkali plant effluent discharge at the northern part of the bay that operated until 2004; and (2) the Qishon estuary which contains effluent from nearby industries. These are in addition to diffusive sources as atmospheric deposition and runoff. Sediment cores in and off Haifa bay area were collected and analyzed for Hg concentrations. Cores were collected from the top of a calcareous sub-marine ridge north of the bay (water depth 36m) and from the continental shelf west of the bay (66m). A third core (6m) was collected in the bay offshore the chlor-alkali plant and previous data from cores collected at this site between 1985-2011 was re-evaluated. The core from inner part of the bay shows a peak in concentration (420 ng/g) at 20 cm below the sea floor, and Hg decreases towards the top. Comparing this core with previous cores collected from the same location presents a continuous decrease in total Hg along the years due to burial and dilution of the contamination by cleaner sediments. On the other hand, the northern core located at the long shore currents direction outside the bay, shows significant Hg enrichment (130 ng/g), 6-fold increase above background levels. The western core also shows a 2-fold increase (20 ng/g) in the upper few centimeters. These patterns may reflect the re-suspension and seaward transport of contaminated sediments. Grain size distribution and <sup>210</sup>Pb dating of the sediments is being researched these days to point out possible interactions, mechanisms and fluxes of pollutant migration via sediments transport.

## Coulomb failure stress change in heterogeneous crust; case study for the 7.2 Mw Nuweiba earthquake

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The Coulomb criterion, which requires that both the shear and normal stress on an incipient fault plane satisfy critical conditions, is the most widely used condition of rock failure. Changes in Coulomb stress associated with one or more earthquakes may trigger subsequent events and produce an aftershock series, where faults are optimally orientated for failure as a result of the stress change caused by the main shock. The Coulomb-3 software calculates the Coulomb failure stress changes directly from the co-seismic slip data. The calculations are made in an elastic halfspace with uniform isotropic elastic properties following the analytical solution of Okada (1992) and thus ignore effects associated with the crustal structure. The COMSOL software operates with a final element grid and enables to take into account the complex structure of the simulated domain. COMSOL calculates the whole stress tensor in every volumetric grid element, which is used. It then calculates the Coulomb failure stress changes. First, we run a series of benchmarking simulations for homogeneous crust and compare the results with those obtained using the Coulomb-3 software. Then, we repeat the modeling for the flat layered structure. The results present a significant difference (in scale of 1.6 [bar]) of the Coulomb failure stress change simulation images. This difference increases with the depth and extend value of maximal change around 6.3 [bar] at the depth of 21.64 km (depth of the mantle). The last series of simulations were performed for the study area including the southern part of the Dead Sea fault, from the Arava Valley to Nuweiba-at the Gulf of Eilat. The crustal structure was constructed using the available geophysical observations (seismic profiles, Gulf of Eilat-bathymetric data and more). The model consists of four layers: the sedimentary succession, the seismic basement and the upper mantle. Stress simulations were performed using co-seismic slip data from the 3-D earthquake modeling based on integrated seismological and INSAR data for the November 22, 1995 Nuweiba earthquake (Baer et al., 2008). The comparison between the results of homogeneous and flat layered models to those obtained for the structural model demonstrate that the Coulomb failure stress change distribution is significantly affected by the heterogeneity of the study area. The difference is around 9 [bar], increases with depth and extends to a maximal change value of around 10 [bar].

## Characterizing provenance sources of the siliciclastic Cambrian Formations using iso-geochemistry of heavy minerals

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The Cambrian siliciclastic sequence exposed in southern Israel represents the first accumulation of terrigenous sediments on the Israeli Precambrian continental basement. Previous studies of this succession indicated a general northward transportation of sediments, most likely from the Arabo-Nubian Shield (ANS) and other distant terrains. Because of their nature, the source of siliciclastic sediments is difficult to define. In the current study the heavy minerals fraction was chosen as proxy for distance source/s. The heavy minerals fractions of seven samples from Amudei Shelomo (AS) and Shehoret (SH) formations were separated and studied using iso-geochemical parameters. In addition, bulk sample petrography was studied using SEM+EDS. Observations show better sorting and roundness in SH compared with AS, indicating higher maturity in the former. In addition, it was found that the heavy mineral assemblages in both formations consist of zircon, rutile, apatite, barite and ferrous oxides. Elemental composition shows a uniform pattern for AS samples and variations among the SH members. The same behavior is observed for the Rare Earth Elements (REE) distribution. The Pb and Sr isotopic composition was determined for all samples. Results show that all samples evolved from the same U-Th source. However, on  $^{206}\text{Pb}/^{204}\text{Pb}$  vs.  $^{207}\text{Pb}/^{204}\text{Pb}$  and  $^{207}\text{Pb}/^{204}\text{Pb}$  vs.  $^{208}\text{Pb}/^{206}\text{Pb}$  plots the AS samples form a tight and distinct low values group. The  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio values of AS are significantly lower than those of SH samples, and in both formations no correlation was found with  $1/\text{Sr}$ , suggesting one or more than two Sr end members. A good correlation was observed between the isotopic composition of  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio with  $\text{Sr EuN}/^*\text{EuN}$  suggesting that apatite dominates  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio. Similarly,  $^{208}\text{Pb}/^{206}\text{Pb}$  and  $^{207}\text{Pb}/^{206}\text{Pb}$  ratios are correlated with  $\text{LaN}/^*\text{LuN}$  indicating that epidote group mineral might dominate the Pb isotopic composition.

## Mechanical and Petrophysical Behavior of Oil shale from the Judea Plains, Israel

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We studied the geomechanical and petrophysical properties of the Shefela oil shale in the Aderet borehole, central Israel and their changes under pyrolysis. The oil shale is dark brown chalk rich in organic matter (OM), with up to 20% TOC at the Ghareb formation in the middle of the investigated section. The porosity of the oil shale is high (approx. 37%) and the permeability is very low (approx. 0.09 mD) and strongly anisotropic, the vertical flow is more restricted relative to horizontal flow along the bedding planes. At room temperature, the rock exhibits a brittle behavior, the failure of which can be described by both the linear Coulomb-Mohr criterion and by the non-linear Griffith's criterion. The cohesion and the angle of internal friction obtained are 5.51 MPa and 10.7°, respectively. The uniaxial compressive strength averages 19 MPa at the Ghareb interval. The Brazilian tensile strength averages 3.1 MPa at dry conditions and decreases with increasing water content to a value of 2.6 MPa on average for a water content of approx. 25%, being higher by 1.7 on average for the parallel to bedding tension. The porosity and the permeability are relatively independent of organic content before pyrolysis. However, the release of liquids and gases from the OM during thermal maturation in the pyrolysis experiments and volume reduction of the OM creates new space. This develops a finer secondary pore structure within the OM, enhancing the porosity by an average factor of 1.28 up to a maximum value of 62%, with relatively small variation due to changes in pyrolysis conditions. The permeability is strikingly enhanced by almost an order of a magnitude on average (up to of 6.5 mD). The amount of OM loss depends on its initial content and the pyrolysis conditions. Applying back pressure seems to increase the amount of residual OM remaining in the rock and decrease the porosity growth. Moreover, slowing down the rate of temperature increase during the pyrolysis seems to have a similar effect but to a much lower extent. The degree of thermal permeability enhancement is also related to the amount of OM initially in place but is independent of pyrolysis conditions and can be estimated if the initial OM content is given. These results are valuable for in situ thermal production of oil and gas from bituminous chinks and contribute significantly to the understanding of primary accumulation of shale oil and gas and migration of oil and gas from source rocks.

## A New Look for the Gravity Map of Israel

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The Bouguer anomaly map of Israel was created from data-sets that contain approximately 56,000 gravity measurements collected over the years. All these measurements were processed with reference to the 1967 reference ellipsoid. The processing included the free air, terrain, and Bouguer plate corrections and was digitized in order to create the national gravity map of Israel. The map is very sensitive due to a  $2.67 \text{ gr/cm}^3$  density value used for the Bouguer correction. This value has been used over the years and corresponds with the mean density of the Judea Gr. lithology, and deeper lithologies. The Bouguer correction's purpose is datuming and should use density values from shallower lithologies. There are several outcrops of the Judea Gr. in Israel, but most of it is buried under the surface covered by overlay layers with density variations from  $2.0$  to  $2.55 \text{ gr/cm}^3$  as the depth increases. This contrast of the lower overlay layers with the Judea Gr. expresses the main features of the national gravity map of Israel, which is highly correlated with the structure of the top Judea Group. These features obscure the effect of the lower surface anomalies. Using a different value of density, one that is more suitable for the Cenozoic lithology and in a different way, should suppress the influence of the Judea Gr. and reveal the gravity anomalies of the lower surface. A new gravity map was created from compiling the gravity measurements with the top Judea Gr. map. Two different densities were used for the Bouguer correction,  $2.55 \text{ gr/cm}^3$  for Judea Gr. and  $2.2 \text{ gr/cm}^3$  for younger deposits. These values were selected as the mean contrast between the lithologies after reviewing the literature and well logs data. The new gravity anomaly map is different in a way which the patterns of the elongated anomalies is shifted to the east and appears wider and smoother. The Carmel positive anomaly higher value stays the same and the south region of Israel has a higher East to West gradient. To enhance our understanding of the new gravity anomaly map, a process of modeling is needed and new and improved measurements as well.

## Subsurface mapping of Northern Negev: Phase I – collecting data

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The Geological Survey of Israel is building a database of subsurface structure and stratigraphy in the northern and northwestern Negev, based on all seismic surveys and well logs collected. This database will serve for location of suitable sites for subsurface storage of CO<sub>2</sub> emitted from power plants, and for estimation of the volume that can possibly be stored there. For this propose of 3D geo-modeling we focus on seismic lines and borehole electric logs. During the first phase of the project 570 2D reflection lines with a total length of c.a. 7,000 km were examined. This dataset is comprised of two different data formats, handled by different approaches. 1. Half of the seismic lines, those with digital (SEG Y) format, were reviewed and their spatial configuration was validated and corrected. The coordinates of these lines (shotpoint or CDP) were transformed from ITM to UTM. Then, these lines were loaded to the Kingdom (IHS) seismic interpretation software. Special attention was paid to the compatibility of the datum of each line to the project environment. 2. The other half of the seismic lines, those without a digital format, only exist as hard-copies. All the paper sections of these lines, including their different processing versions, were scanned and a digital archive was established for them. We intend to convert some of these lines to digital (SEG Y) format. A major part of the project, which is still ongoing, is reprocessing of all lines that can be improved. This reprocessing is based on raw data and original observer logs copied from the national archive at the Geophysical Institute of Israel. Reprocessing is carried out by the Polish company Geofizyka Krakow. Until now 68 lines, totaling to about 1,300 km, were processed to Pre Stack Time Migration. For the next stage of interpretation that requires tying seismic horizons to known stratigraphic units, we gathered electric well logs, velocity surveys and lithology information of most of the deep wells in the study area.

## CO<sub>2</sub> storage capacity assessment in the deep saline aquifers of southern Israel

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Elevated concentration of CO<sub>2</sub> in the atmosphere is considered by many to be one of the major reasons for global warming and climatic change; thus, reducing anthropogenic emissions is an important measure that needs to be taken. Capture of CO<sub>2</sub> emitted from industrial sources and its underground storage was suggested as a rapid and significant mitigation method. We describe the geological characterization and capacity assessment of long-term CO<sub>2</sub> storage capability of selected subsurface deep saline aquifers in southern Israel. Current predictions estimate that between 2025 and 2075 the total CO<sub>2</sub> emissions in Israel will sum up to 7 Gt. Considering these numbers we present a preliminary assessment of geological storage within a few km thick section (Precambrian to Early Cretaceous), which extends from below a major freshwater aquifer down to the crystalline basement. Using geologic data from 180 oil and exploration wells, we mapped three reservoir-quality units located within the optimum depth range of 800-2500 m below surface, each with its own topping sealing unit. The lower aquifer (Cambrian to Early Triassic) is about 1,000 m thick, and consists mainly of terrigenous sediment (fluvial sandstone and shale) with some marine intercalations. This aquifer is topped by up to 900 m of shales, carbonates, and evaporates. The middle aquifer (Jurassic) is up to 2,000 m thick, and composes mainly of sandstone and fractured limestone units topped by up to 400 m of marine shales. The upper aquifer (Early Cretaceous) is up to 600 m thick of nearly pure sandstone, and is well separated from the overlying freshwater aquifer. Water salinity in all three aquifers is generally above 3,000 mg/L, and could extent as high as 210,000 mg/L. Capacity calculations are based on the USDOE methodology, using an effective storage capacity coefficient of 2%. The results of our study indicate that the effective storage potential of the middle and lower aquifers is 4.4 Gt; and 1.8 Gt., respectively (6.2 Gt in total). We further estimate that additional 8.7 Gt can be stored within deeper portions of the lower and middle aquifers, below the 2,500 m optimum depth barrier. In conclusion we point out that geological storage in Israel is certainly feasible. Considering only saline aquifers and only the southern part of the country, we identify a storage capability of 15 Gt, which is about twice as much as the country's needs for the next 50 years. Moreover, these targets are located in a poorly populated area, not too far from the main power plants (main CO<sub>2</sub> sources), and do not threaten the regional freshwater aquifer.

## Structural and stratigraphy evolution of the Dead Sea Lake: Insights in an active strike-slip basin

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Understanding hydrogeological dynamics of the Dead Sea Basin (DSB) is essential for unraveling regional to global climatic patterns in the geological past. Climatic reconstruction based on combined lithological and geochemical analyses reveals that a series of water bodies and palaeolakes occupied in the DSB, from the Neogene to the Quaternary. Previous multi-proxy studies, concentrated mainly on exploring the exposed surrounding sediments along the lake's coastline, revealing that they contain the sedimentary record of several glacial-interglacial periods. Nevertheless, despite generally good outcrops, complete and continuous sedimentary sequences of these intervals in the field are not well-preserved and crucial lacustrine sections during low lake stands are not exposed. Yet very little is known about the different stratigraphic formations and subsurface lithology in the Dead Sea itself (lake), especially those deposited during glacial events. In addition to lake-level depositional systems, tectonic related features such as faults and diapirism, influence the geometric distribution of syn-rift sediment. Moreover, historically known large earthquakes have struck the region in the past. One such example is the partial destruction of Jericho, Nablus and Jerusalem in 1927 by a  $M_w=6.2$  earthquake. Among other things, lack of sufficient data and survey coverage impede our ability to obtain a comprehensive picture of active basin dynamics. To help address this issue, two seismic-reflection surveys were carried out during the last two years (2010-2012) and a total of 65 seismic profiles were collected. These high-resolution Sparker surveys were aimed at locating and identifying tectonic related features and to help complete the information gap by emphasizing new insights on lake sedimentary infill and its relation to changes in climate and seismic activity. The deepest area of the lake shows a maximum seismic penetration of around ~40 to 80 m depth using this method. Generally, data show a ~70 to 100 m depth of sedimentary infill with a series of highly reflective seismic horizons. Preliminary results indicate a complex lacustrine depositional system with seismic stratigraphic units and seismic geomorphological features that can be interpreted as previous lake-level changes and may serve as regional climate and local tectonic signatures in an active pull-apart basin. Based on these new high-resolution seismic profiles combined with downlogging data recovered during the ICDP (International Continental Drilling Program) DSDDP coring campaign in 2011, this study strives to provide detailed information about the evolution of the Dead Sea basin since approximately the Middle Pleistocene and

will improve our understanding of neotectonics and glacial-to-postglacial stratigraphic sedimentary processes that affected the lake. Achievement of these objectives will contribute accurate evidence of palaeoclimatic evolution in the context of the Levantine basin.

## Shefa Yamim – Modern Diamond and Precious Stone Exploration in Israel

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Shefa Yamim is the only company in Israel focusing exclusively on the exploration and development of diamonds and precious stones. Since 1999 Shefa Yamim has been exploring the potential of Mount Carmel and adjacent areas in northern Israel where occurrences of such minerals have been discovered. The granting of exploration and prospecting permits covering some 660,000 Dunam has given Shefa Yamim exclusivity to explore and assess the mineral potential of these regions. Shefa Yamim's primary interests encompass two specific areas: The Kishon River (alluvial deposits) and Mount Carmel (primary deposits). The Kishon River is a graben environment hosting a variety of inter-bedded sedimentary deposits, ranging in age from recent to Cretaceous: alluvial fan, marine, lagoon and fluvial. Shefa Yamim has discovered diamonds, natural moissanite and corundum (ruby, sapphire) in these sediments. Of particular interest is the occurrence of exceedingly rare natural moissanite (SiC). Mount Carmel, an upland region, hosts major volcanic complexes intruding primarily Cretaceous marine sediments. Building on the work by Eytan Sass and Amit Segev, we have identified a number of volcanic bodies here. While not considered a classic kimberlite/diamond geological cratonic terrain, northern Israel shares similarities with several non-traditional diamond producing regions worldwide. The fourteen known Volcanic Complexes in Mount Carmel include basaltic to kimberlitic composition vent and extra-crater deposits of locally bedded and resedimented pyroclastic rocks of volcanoclastic texture. These are largely Cretaceous in age. We have demonstrated that some have clear kimberlitic affinities based on petrography, geochemistry and the mineral chemistry of Kimberlitic Indicator Minerals. More significantly, the recovery of a micro-diamond from the Rakefet Magmatic Complex suggests that these kimberlitic bodies can potentially be diamond-bearing. Shefa Yamim utilizes standard exploration techniques in a staged approach for both primary and alluvial deposits. These techniques include prospecting/mapping and heavy mineral sampling coupled with modern analytical techniques, geochemistry, geophysics, mineralogy and GIS data management to explore for diamond and precious stones. Shefa Yamim operates a bulk sample processing plant, exploration sample treatment facility, heavy mineral laboratory and microscopic sorting laboratory in Akko, and relies on outside laboratories for specialized analyses. Exploration is ongoing, building on early stages to develop a continuum of advanced stage projects of increased scale, complexity and cost. Highlights of

exploration to date include the recovery of 77 diamonds up to 0.88 carats in weight, thousands of gem natural moissanite grains (up to 4.1mm) and thousands of gem corundum (sapphire and ruby) grains up to 5.72 carats.

## Predicting soil thickness and dust content in upland watersheds: A case study from the Mojave Desert

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Soil thickness is an important input parameter for hydrologic models. As the spatial distribution of soil thickness is strongly variable at hillslope scales, modeling soil thickness at the watershed scale is needed if we are to accurately model hydrologic and geomorphic processes that depend on soil thickness. Recent studies have demonstrated that numerical models which assume a long-term balance between soil production and soil erosion can accurately predict the spatial distribution of soil thickness in semiarid and relatively humid areas, where soil thickness varies gradually along hillslope profiles. Yet, these models have not been tested in arid regions, where soil thickness varies abruptly and where the influence of dust accretion on soil thickness may be much more significant. In this study, we developed and tested a numerical model for the prediction of soil thickness and dust content in an arid mountainous area of the Mojave Desert, using field measurements of soil thickness, geochemical analyses of soil and bedrock samples, and quantitative analyses of LIDAR data. The study site is characterized by thin soils (<1-2 m) and extreme variability in soil thickness at essentially all spatial scales. Soil production rates in the model were quantified using exponential and humped soil production functions, and soil erosion rates were quantified using the nonlinear depth- and slope-dependent transport function, assuming that only the upper soil horizons (A+B) can be transported. We calibrated the soil production and dust accretion rates in various plutonic lithologies (granite, diorite, and quartz monzonite) using 1) field data of soil thickness, and 2) dust content of the soil estimated by analysis of immobile element concentrations. We validated the model results using measured data on soil thickness and the presence/absence of soil in an attempt to adequately represent the great spatial heterogeneity in soil thickness at our study sites. We found good agreement between observed and predicted soil thickness and dust content in soil. Our results show that we can simultaneously predict the soil thickness and the fraction of eolian dust in the soil at different sites across the landscape.

## Seismotectonic analysis and probabilistic seismic hazard assessment for a site in northern Israel

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The currently-evolving regulatory demands for Seismic Hazard (SH) assessment in Israel, following international practice, define the following two main stages:

- a. Screening for the presence of threshold conditions for specific hazards: Surface rupture due to active faulting; amplification of ground motions; landslides; liquefaction; and tsunami.
- b. Site specific studies in compliance with the requirements of seismic design codes and Environmental Impact Assessments (EIA); and as a mean of providing seismic design parameters.

The prerequisite for a site specific study is to perform a seismotectonic analysis: The Peak Ground Acceleration (PGA) or the response spectrum expected at the top of the hard rock layer at the site. These were estimated for a site in northern Israel by performing a Probabilistic Seismic Hazard Assessment (PSHA) in the following stages: First, an extensive characterization of linear seismic sources (faults) was used for the assignment of MMAX for major faults closer than 200 km to the sites by estimating their length and width. In addition, published data was used for the determination of each fault's most probable slip rate. Using the New Generation Attenuation Relationships, the PGA generated by MMAX for each fault was estimated at the site; only faults with PGAM(MAX) at the site  $>0.1g$  were used for the PSHA analysis. The largest PGAM(MAX) is, by definition, the Maximum Credible Earthquake (MCE) for design purposes. Following, the moment release rate was estimated based on the slip rate. The frequency-magnitude density distribution function for  $4 < M < M_{Char} - 0.12$  ( $M_{Char}$  = Characteristic Earthquake = MMAX, a conservative approach) was estimated using the seismic parameters  $\alpha$  and  $b$  of the corresponding seismic zone (Shamir et al., 2001). The moment release rate corresponding to this exponential was subtracted from the overall moment release rate for the fault, and the remainder moment release rate was used for the development of normal distribution of frequency-magnitude density distribution function in the interval  $M_{Char} \pm 0.12$ . The typical ratio between the contribution of the exponential and the characteristic parts of the density distribution function to the overall moment release rate is 0.2:0.8. The hazard curve (PGA-Frequency space) for each fault was calculated using the software OpenSHA. The cumulative probabilistic contribution of all qualified faults in the seismotectonic model to the seismic hazard at the site (the combined hazard curve) in the interval  $4 < M < M_{MAX}$  was calculated using a floating epicenter. The PGA at the site for a return period

of 10% in 50 years is only slightly larger than the corresponding SI 413 value. However, disaggregation of the results show dominant contribution of the plate-boundary faults to the seismic hazard at the site in this analysis, compared with significant contribution of low-seismicity zones (e.g. Galilee) to the seismic hazard at the site according to the SI 413 model.

## Geological constraints and alternatives for natural gas processing stations and transportation routes offshore the northern coast of Israel

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The National Gas Authority has developed a National Master Plan (NMP) to facilitate the transmission of natural gas from Israel's offshore discoveries to the onshore gas distribution system. This requires the construction of a gas treatment rig and facilities on the continental shelf and their connection, with a pipe, both to the deep sea gas fields and the onshore facilities. Here we examine the geological and seismic hazard considerations in selecting location alternatives for the offshore facilities and routes of supply. The current continental shelf was built by a massive Pliocene and younger clastic sedimentary column overlaying the Messinian evaporates. The shelf slopes westward 10 m/km on average to a distance of >20 km off central Israel, but narrows northward and in places where the Palmachim and Dor slumps developed. The continental slope offshore northern Israel starts at water depths of ~100 m and begins to level out at water depths of ~1000 m. Using high resolution (5 m) multi-beam data, a detailed delineation of various geomorphic seabed features was performed offshore between Haifa and Tel-Aviv. These include: pockmarks, lineaments, erosional scarps, channels and depositional lobes. Three different zones were identified along the continental slope: a) in the north is the known Dor disturbance characterized by huge slumping scars and canyons; b) in the center is a high density zone of N-S morphological steps, and slumping scars; and c) in the south a zone with relatively few lineaments and scars. The southern zone is bounded in the south by the Palmachim disturbance. In general, local maximum slopes decrease from ~20° in the north to ~7° in the south. The N-S morphological steps along the slope, which are suspected as expressions of active deformation processes, were correlated with faults that were identified in multichannel seismic profiles. These faults typically terminate into the Messinian evaporates. Pockmarks on the continental shelf range in size between a few tens of meters to more than 100 m, and their maximum depths are estimated at ~10 m. The pockmarks appear in clusters along a ~4 km wide N-S strip at water depth of 80 to 120 m. This strip is characterized by an undulating sea bed, with typical wavelength of ~100 m and amplitude of ~10 m. Both pockmarks and the undulating seabed feature were attributed by other studies to gas seepage. Based on stability, seismic hazard- and statutory considerations, the NMP includes three alternative areas for the location of an offshore treatment facility. These are located at water depths of 60-100 m offshore Dor-Cesarea, Netanya and Poleg. The results of this study also allowed us to design and compare 1 km wide alternative corridors for gas transportation across the continental slope to the offshore treatment sites.

## Screening Methodology for Preliminary Seismic Hazard Assessment

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The currently-evolving regulatory demands for Seismic Hazard (SH) assessment in Israel, following international practice, define the following two main stages:

- a. Screening for the presence of threshold conditions for specific hazards: surface rupture due to active faulting; amplification of ground motions; landslides; liquefaction; and tsunami.
- b. Site specific studies in compliance with the requirements of seismic design codes and Environmental Impact Assessments (EIA); and as a mean of providing seismic design parameters.

Screening Studies are now required by the Ministry of Interior as part of the local and national planning process; by the Ministry of Environmental Protection as part of risk management regarding hazardous materials; by Mekorot as part of the Summary of Design Parameters stage; by the National Road Authority as part of the Initial Design stage; and by various other governmental ministries and agencies. SH Screening Studies typically include an analysis of the potential for surface rupture and delineation of the area susceptible for ground distortion due to fault activity, where further investigation is needed; indication of the expected horizontal peak ground acceleration and preliminary estimation of the potential for amplification due to ground conditions; the potential for slope mass movement based on lithology, layers inclination, slope and expected acceleration; the potential for liquefaction based on expected composition of underground layers, and the groundwater level; and the potential for tsunami flooding. These studies also include a set of instructions for design/planning limitations and for site specific studies derived from the requirements of SI 413 (the Israeli earthquake building code) or an equivalent code. SH Screening Studies are usually based on the hazard maps of the Geological Survey of Israel, the SI 413 Acceleration Map (the Geophysical Institute of Israel), and on publically available information. The country- or regional-scale resolution of these data usually imply that accuracy is limited, often leaving much room for the geologist' interpretation based on his/her knowledge and experience. General aspects of the screening studies and a case study will be presented in the meeting. A separate abstract by the same authors is dedicated for SH site specific studies.

## The distribution and S isotopes of individual sulfur compounds in oils generated by pyrolysis of Ghareb oil shale

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We study how induced thermal maturation affects the distribution and S isotope ratio of individual organic sulfur compounds (OSCs) released from the immature, sulfur rich Ghareb oil shale. Also, we attempt to use OSC to evaluate the degree of thermal maturation and hydrocarbon potential in the oil shale and the petroleum-source rock correlation. We used a Ghareb oil shale core sample from the recent Aderet 1 drillhole of IEI Ltd. A series of semi-open dry pyrolysis experiments were conducted at slow heating rate of 4°C a day. The initial and residual solid rock were extracted and their bitumen was isolated and fractionated by polarity using liquid chromatography. Liquid and gas samples were collected in intervals of 25°C. The organic fractions were analyzed then by GCMS to identify and quantify hydrocarbons and especially OSCs. A fraction of these samples was analyzed for  $\delta^{34}\text{S}$  in individual OSCs by GC coupled to multi collector inductively coupled plasma mass spectrometer (GC-MC-ICPMS). Preliminary results show that the OSCs have a unique thermally dependent sequential molecular distribution. Thiolanes were released in the initial stages of the pyrolysis and their concentration rapidly decreased when alkylated thiophenes reached maximum concentration. Benzothiophenes reached maximum where dibenzothiophenes begin to form. Normal hydrocarbons (no OSCs) form at higher rates with relatively short chain length (up to n-C<sub>22</sub>). The  $\delta^{34}\text{S}$  values generally increased with temperature up to 3-4 permils for alkyl thiophenes and sulfides relative to the initial samples that were collected at 250°C. Benzothiophenes and dibenzothiophenes were consistently  $^{34}\text{S}$  depleted compared with alkylated thiophenes and were closer to that in the raw kerogen value. These preliminary results show that the combination of individual OSCs distribution and their  $\delta^{34}\text{S}$  values have a promising potential to be used as tracers for the thermal maturation of the source rock and its structural transformations.

## B and O isotopes as tracers of serpentinization along fossil oceanic detachments, Troodos ophiolite, Cyprus

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Serpentine lubricated detachment faults strike parallel to two segments of a paleo spreading center that are separated by the Arakapas transform in the Troodos ophiolite, Cyprus. To the north of the transform, serpentinite faulted against gabbro shows bimodal spatial distribution and covariance of B-O isotope ratios. These data indicate overprinting of fault localized, 'high temperature' oceanic serpentinization ( $\delta^{18}\text{O}=4$  to  $6\text{‰}$ ;  $\delta^{11}\text{B}=-3$  to  $3\text{‰}$ ) by widespread late hydration at lower temperatures, forming abundant chrysotile veins ( $\delta^{18}\text{O}=10$  to  $12\text{‰}$ ;  $\delta^{11}\text{B}=7$  to  $13\text{‰}$ ). At the Limassol Forest complex, south of the transform, extensive talc-amphibole-chlorite metasomatic zones and rodingitized gabbro boudins occur within strongly foliated serpentinite shear-zones separating an ultramafic section from sheeted dykes.  $\delta^{18}\text{O}$  values of serpentine from shear-zones in the Limassol Forest have a narrow range and are invariably lower than mantle values ( $1$  to  $5.7\text{‰}$ ;  $n=26$ ), consistent with serpentinization during seafloor spreading.  $\delta^{11}\text{B}$  (Srp) values are more scattered ( $5$  to  $27\text{‰}$ ) and weakly correlate with boron contents ( $2$  to  $60$  ppm), which might be accounted for by increase in pH of water as serpentinization progressed. Absence of the lower crustal section above the mantle and injection of gabbroic magma followed by localized serpentinization, metasomatism and deformation along this discontinuity are major characteristics of oceanic detachments. Isotope systematics strongly resemble those of serpentine recovered from modern oceanic core complexes such as the Atlantis Massif. The mantle sequence of the Limassol Forest is thus suggested to have been exhumed at the footwall of an oceanic core complex. This scenario sheds light on the location of the spreading axis south of the transform and explains the highly complicated structure of the fossil ridge-transform intersection of the Limassol Forest.

## The Late Pleistocene-Holocene sedimentary evolution of Zevulun Plain – focusing the wetlands

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The existence of Holocene wetland sediments in the subsurface of Zevulun Plain of Israel has long been known, yet their spatial and temporal distributions remained indefinite. The current research presents a reconstruction of the wetlands time span, conditions and the sedimentary setting leading to their formation. A terrestrial and marine sedimentary sequence of three cores was recovered from Zevulun Plain, and analyzed by sedimentological and paleontological methods and dated by <sup>14</sup>C and luminescence. The results revealed two separate wetland regions to the north and south of the plain, both of them occurring during the Early-Holocene sea level rise, yet not synchronously in time. The northern wetland originated ca. 7,520 cal. BP, sustained around a 1,000 years and ended 6,230 cal. BP as the southern wetland originated (6,490 cal. BP). The southern wetland ended as well approximately 1,000 years later ca. 5,430 cal. BP. In addition, the geographical distribution of the wetlands illustrates a spatial connection between the major modern rivers flowing through Zevulun Plain. Conditions of fresh water wetland environment were indicated by the faunal assemblage and floral remains dominated by the fresh water algae *Chara* sp. and the water plant *Cladium mariscus*. However, some of the faunal assemblages: the benthic foraminifera *Trichohyalus aguayo* and the bivalve *Cerastoderma glaucum*, indicated a transition to slightly brackish conditions at the top of both the north and south wetland sediments. Overall, the sedimentary sequences from the north and south of the Zevulun Plain display a Late Pleistocene–Early Holocene terrestrial sediments (soils or fluvial) covered by Early-Middle Holocene wetlands. The wetlands terminated as the sea level rose covering the wetlands with marine sands later on replaced by aeolian sand dunes. The environmental changes, which occurred in Zevulun Plain through the Holocene emphasize the transient processes taking place along the Israeli coast. These changes are coupled with the pattern of the Bronze Age urban settlements as Tel Zibda and Tel Afek excavated along the plain.

## Mapping of salt layers through Dead Sea sinkhole development areas using MASW method

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The Dead Sea (DS) coastal areas have been dramatically affected by sinkhole occurrences since the 1990's. It has been shown that sinkholes along both Israeli and Jordanian shorelines are linked to evaporate karst cavities that are formed by slow salt dissolution. The location of sinkholes suggest that: (1) the salt weakens as the result of unsaturated water circulation, thus enhancing the karstification process; (2) sinkholes appear to be related to the decompaction of the sediments above karstified zones. The location, depth, thickness and weakening of salt layers along the Dead Sea shorelines, as well as the thickness and mechanical properties of the sedimentary deposits above it, are thus considered as controlling factors of this on-going process. The knowledge of shear-wave velocities ( $V_s$ ) would shed light on mechanical properties of both salt and its overburden. We have suggested  $V_s$  estimation using the Multichannel Analysis of Surface Wave (MASW) method, based on multichannel data acquisition of surface-waves, generating of dispersion curves and their inversion. Two approaches have been used.  $V_s$  mapping has been performed along the Israeli shoreline, to discriminate weak and hard zones within salt layers, after calibration of inverted  $V_s$  near boreholes. It has been shown that there is  $V_s$  increase from sinkhole sites (salt edge) toward the DS. Initially examined weak zones, located near the salt edge, associated with karstified salt, are characterized by  $V_s$  values of 760-1050 m/s, and extend 60 -100m from salt edge in the DS direction. Hard salt zones with velocity  $V_s$  values greater than 1500 m/s are located at distances of more than 100-220m from salt edge. Finally, transition zones ( $1,050 < V_s < 1,500$  m/s) have a 40-160m spread. At second stage we estimated in situ hydraulic conductivity  $K$  in boreholes (using ultrasonic shear wave velocity  $V_s$ ) and in salt layers from the surface (using seismic shear wave velocity). Such estimation is constructed on inter-relationships between  $V_s$  and  $K$ , obtained (1) in laboratory conditions using ultrasonic techniques and (2) in-situ where  $V_s$  velocity is correlated with  $K$  measured by Magnetic Resonance Sounding methods. Our evaluation has shown that for in-situ salt, hydraulic conductivity varies between slightly higher than  $K=10$  m/s in the sinkhole sites close to the salt edge to slightly higher than of 10 m/s, in sites close to the Dead Sea shoreline.

## Determining Seawater Age in Israel's Mediterranean Continental Shelf Using Radium Isotopes

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Cross-shore mixing of the inner and outer shelf water is of high importance to the conveyance of chemicals and contaminants from the coastal area to the open ocean and vice versa. However, cross-shore inner shelf currents were hardly studied, in particular in the Levantine basin (e.g. Rosentraub and Brenner, 2007; Efrati et al., 2012). In this study, an attempt was made to quantify the age of the outer shelf water using radium isotopes. Water age is defined here as the time since the water last interacted with the coastal sediments. There are two advantages in using radium isotopes for this purpose. First, radium is enriched in groundwater and pore water while pretty low in seawater. Second, the wide range of half lives (1600 years to 3.7 days) of the different radium isotopes allows the study of processes of various time frames. Surface seawater samples were collected on board R.V. Shikmona during a cruise in 29-31.8.2011. Samples were collected across the whole Mediterranean continental shelf of Israel from 10 to 100 m water depths, using the vessel pumps. The activities of the long-lived isotope  $^{226}\text{Ra}$  ( $\tau_{1/2} = 1600$  yr) were not significantly different from those of open seawater. The short-lived isotopes  $^{228}\text{Ra}$  ( $\tau_{1/2} = 5.75$  yr) and  $^{224}\text{Ra}$  ( $\tau_{1/2} = 3.66$  d) showed activities significantly higher than in the open Mediterranean (2.7-9.4 and 0.2-2.0 dpm/100L, compared with  $<2$  dpm/100L and  $\sim 0$  in the open Mediterranean, respectively) and decreasing activities from shallow to deep water. We used  $^{224}\text{Ra}$  activities in order to determine the age of outer shelf water (100 m water depth).  $^{224}\text{Ra}$  activities were normalized to  $^{228}\text{Ra}$ , as to take into account the mixing with open sea factor, assuming that the times involved are much smaller than the half life of  $^{228}\text{Ra}$ .  $^{224}\text{Ra}/^{228}\text{Ra}$  was consistently dropping from the inner shelf to the outer shelf (0.21 to 0.07 average values). Since we do not have the shoreline activities of  $^{224}\text{Ra}$  and  $^{228}\text{Ra}$ , we used the surface water activities measured at 10 m depth as the time zero activities. Our calculations suggest that the average age of outer shelf water is  $6.5 \pm 1.5$  days. There is one exception west off Haifa bay, where the outer shelf water is much younger ( $\sim 2$  days).

## General regularities of Mantle aspects of oil/gas forming

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This research is the final in a series of studies (that have been reported previously at IGS conventions) on elucidation regularity between diverse parameters of volcanic- mantle characteristics for mix (oil and gas bearing, and not productive together) rift system. These rifts are: Red Sea, Ethiopia, Dead Sea, Rein, Baikal, Dneprovo-Doneck, South Caspian, Rio-Grande, West Siberia as well as others. Regularity between the following characteristics of rifts was studied: Age, Period of Magmatic Activity, Roof of Mantle, Partial melting degree of Mantle and Intensity of Magmatic Activity. The investigations show the following results: 1) –in contrast to the general aging of the Earth, in the rift, the intensity of magmatic activity increases, while a dependence between Roof of Mantle and Intensity of Magmatic Activity was not observed. 2) - oil and gas bearing rifts can be of all ages, but nonproductive ones are limited only to rifts younger than 70 million years .3) - This distribution corresponds to the model of degassing of hydrocarbons from super deep sources.

## Determining the time span and formation rates of Israel coastal cliffs using archaeological and geological markers

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The coastal cliffs of Israel have significant effect on human access to the coast and its uses. It is important to understand the time span and rates of their formation. Previous studies monitored the cliffs using field observations and aerial photographs. These provided valuable information on the last centuries. Archaeological and geological features, however, may be used as markers for longer processes. Underwater and coastal archaeological and geological research in recent decades revealed shipwreck, anchorages, coastal installations and natural features, which are used to calculate the formation rate and formation time of the coastal cliffs. The finds suggest that in central Israel, where the Kurkar sandstone is poorly consolidated, the initial main phase of coastal cliff creation took place during a relatively short period between 4500-4000 BP. Human activity and sea level rise in the last 100 years accelerated coastal erosion, cliff retreat and the formation of new cliffs.

## Geomorphic changes in drainage systems in the southern Arava as indicators for recent tectonic activity

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The Elat area is considered to be one of the most seismically hazardous regions in Israel in large due to very recent tectonic activity on the Elat fault system. While the distribution over time of this activity has been thoroughly studied in a series of recent paleoseismic and historical investigations, our understanding of the spatial distribution of young deformation in this region remains less clear. In this context, the goal of our study is to improve the current understanding of the spatial distribution of late Quaternary tectonic deformation in the southern Arava through interpretation of recent changes in the characteristics of drainage systems due to tectonic activity. Field based geomorphic mapping of late Quaternary alluvial units and detailed high-resolution topographic cross-sections across the Amram and Shehoret chronosequences indicate a number of recent changes in stream flow directions that are most-likely related to tectonic tilting. We find recurring geomorphic evidence for southward tilting in the Amram fan sequence and northward tilting in the Shehoret fan sequence that suggest off-axis compression. Initial OSL results indicate that the latest episode of the tilting activity is within the time frame of early to middle Holocene.

## 3D reservoir model for geological CO<sub>2</sub> storage at the depleted oil fields and deep saline aquifers

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Regional and local reservoir mapping and characterization is critical for successful geologic storage of carbon dioxide because of the many physical and chemical processes impacting CO<sub>2</sub> movement and containment under field conditions. For this purpose structural, litho-stratigraphic and lithofacies studies and petrophysical interpretation were carried out on the basis of well log data, hydraulic well testing, cores and small cuttings analyses from 104 wells within the Kokhav-Heletz-Brur depleted oil fields and Zohar-Kidod Haqanaim gas fields. As a result of these studies, 3D geological model of the Heletz and Kokhav sands (Kokhav-Heletz-Brur oil fields) and Zohar and Inmar sands (Zohar-Kidod Haqanaim gas fields reservoirs) was built. The model is represented by a set of litho-stratigraphic correlations, geological cross-sections, core permeability vs porosity charts and various (structural, isopach, lithofacies reservoir pressure, isosalinity porosity and permeability) maps describing the geological features (litho-stratigraphy, layers geometry, reservoir and cap rock thickness, pinch-out lines, faults) and spatial distribution of petrophysical parameters (porosity, permeability, pressure, water salinity) of the reservoir layers. This geological model provides the foundation for establishing principal trapping mechanisms and delineating local distribution of the reservoir sands and cap rock. Geological and geophysical data generated by these studies can be used in numerical simulations of risk and performance assessment for geological CO<sub>2</sub> and natural gas storage and enhanced oil recovery. 3D model for sands reservoirs will allow construct a comprehensive picture of subsurface geology, estimate reservoirs CO<sub>2</sub> storage capacity and thus will serve the basis for future geological CO<sub>2</sub> storage in Israel. The geological features incorporated into geological model are required for determining the expected evolution of the geological reservoir system after CO<sub>2</sub> injection and conducting long-term monitoring strategy. Thus, a combined approach for the mapping and characterization oil and gas reservoirs is being proposed. This approach is based on the integration of the geophysical (seismic and well logging) and geological data from a digital database.

The basic elements of this methodology are as follows:

1. Lithological reconstructions and stratigraphic formation analysis.
2. Definition of reservoir petrophysical (porosity, formation fluid properties, net pay thickness) properties.
3. Subdivision of hydrocarbon reservoir into sub-reservoirs.

4. Tracing lithofacies heterogeneity of reservoir.
5. Detection and correlation of high porosity zones, fractures, caverns and karsts development.
6. Delineation and mapping of fault zones.
7. Expanded Composite Logs construction.
8. Construction of the Lithostratigraphic Correlations and Geological Cross-Sections.
9. Construction of Reservoir Structure, Lithofacies, Thickness and Petrophysical Maps.
10. Development of 3D reservoir geological model.
11. Estimation of the reservoir reserves.

## High resolution seismic stratigraphy across the Carmel continental margin, northern Israel – preliminary assessment of neotectonic activity

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The Carmel-Gilboa fault system branches from the Dead Sea fault towards the Mediterranean continental margin. Close to the margin studies consider the Carmel fault as seismically active, while recent publications challenge this claim. Additional faults within the system were previously interpreted up to the seafloor across Carmel continental margin, between southern Haifa bay and Atlit. These interpretations were based on industrial low resolution seismic reflection data. Here we examine the Carmel continental margin through bathymetry data and new marine high resolution single channel seismic reflection data. Seafloor morphology indicates negligible lineaments across the shelf. Subsurface data reveals continuous reflectivity with no evidence for tectonic faulting. Seismic stratigraphy analysis shows five transgressive-regressive depositional sequences divided by four regressive unconformities. Close correlation between these sequences and the local model-based sea-level curve indicates that no faulting developed across Carmel continental margin during the last ~130k years.

## Evidence of Super floods in the Amram copper mines

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The Amram Valley was an important center for copper mining throughout history. Extensive underground copper mines in the soft Kurnuv sandstone appear as long galleries, halls and shafts in different surfaces. Most of the splits are ten meters above the recent streams (wadies). Mining was active mostly through the Nabataean (Roman) and Early Islamic periods. Over 40,000 tons of overburden, mostly white sandstone, were removed from these mines. Half of it is still exposed in Amram Valley beside the ancient mines, and half was carried away by the Amram Stream toward the Arava Valley. In several, fluvial terraces are observed inside several mines are exposed in the mines. Some of the terraces are more than one meter high and contain mostly sandstone pebbles and, in few sites, limestone angular pebbles. Most of the terraces contain also fine quartz grains and some clay, and thin layers can be recognized. In these sites some of the fluvial terraces are cut off and the outcrop is exposed. Some of the shafts were also filled with the fluvial components. An acacia plant remain found in fluvial sediments in one shaft was dated by <sup>14</sup>C to 240 A.D. These sediments are evidence for floods that occurred after the opening of the mines. Signs beside the sandstone walls are fluvial and suggest that some of the galleries were filled with these sediments. Elongated signs of digging picks were discovered in the fluvial sediments, suggesting that workers needed to remove the sediments during mining. Probably part of these sediments were excavated by the workers and part were carried by strong floods and deposited in the lower part of the cave. An extreme rain event occurred in the Amram region on 18.11.2012. More than 30 mm' of rain fell in less than an hour and a strong intensity flood developed in the streams. Degradation of more than 50 cm. in the fluvial deposits was measured in some sites, suggesting a flood that developed on a limited slope area and brought water and sediments to the cave, causing this incision. This event suggests similar ones in the past, some on a larger scale. Detailed study of these fluvial sediments can be a key for the knowledge and understanding of intensity and time of floods during the mining periods, between and after them.

## Estimation of source parameters for nuclear tests from seismo-acoustic data

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The TNT equivalent yield and the source depth are important parameters of a nuclear explosion, conducted discreetly, exhibiting a violation of the Comprehensive Test Ban Treaty (CTBT). Accurate estimations of the parameters provide important information for the international community, thus contributing to understanding technological aspects of a conducted nuclear test. Two underground nuclear explosions conducted by North Korea in 2009 and 2013 were recorded by several stations of Israel Seismic Network. Pronounced minima (spectral nulls) at 1.25 Hz were revealed in the spectra of teleseismic P-waves. For a ground-truth explosion with a shallow source depth (relatively to an earthquake), this phenomenon can be interpreted in terms of the interference between the down-going P-wave energy and the pP phase reflected from the Earth's surface. Based on the null frequency dependency on the near-surface acoustic velocity and the source depth, the depth of the both North Korea tests was estimated ~2 km, different from the value ~1 km informed by USGS. Records of local seismic stations in South Korea are also analyzed, and this spectral null feature was not found due to close distances. Moment magnitudes  $M_w$  and  $M_b$ , estimated from ISN records of teleseismic P-waves, were compared for the two tests and also analyzed relatively to magnitude values obtained by USGS and CTBTO. TNT yield was evaluated based on the ISN magnitude estimations. During large-scale Sayarim on-surface infrasound calibration explosions in 2009 and 2011, the rarely reported Secondary Shock (SS) phenomenon was clearly observed at all sensors at distances 0.1-20 km. Empirical relationships for air-blast parameters - peak pressure, impulse, positive phase duration and SS time delay - depending on distance, were developed and analyzed. The parameters, scaled by the cubic root of estimated TNT equivalent charges, were found consistent for all analyzed explosions, except of SS delays, clearly separated for different explosives, thus demonstrating dependence on the explosive detonation velocity. Obtained results suppose that measured SS delay can be used as a new simple and cost-effective yield estimator based on the developed relationship of scaled SS delay versus scaled distance. The research was supported by the Israel Ministry of Immigrant Absorption.

## Gas Induced Sea Floor Morphology and Sub Bottom Structure

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The Eastern Mediterranean upper continental shelf area is rich in shallow gas. A recent ultra high resolution seismic survey, which continued a previous survey, has helped to find the role of shallow gas production and migration in the continental shelf shallow structure and the upper sediments stability. Gas migration showed a relation to wavy sediment systems as well as “pock marks”, collapse of sediments, sediment compaction and sediment inflation, thus are a key factor in designing both the sub bottom and sea floor morphology. These surveys show how liquefaction of sediments induced by gas migration initiates “pock marks” and sea bottom sediment collapse. Geostrophic circulation of the Eastern Mediterranean Sea transfers these sediments, usually northwards. Bathymetric data, which was obtained through the National Bathymetric survey (IOLR, GSI and SOI), shows (at least approximately) that the upper and lower shelf have high “self similarity” with a scale difference, thus suggesting that these processes are similar in deeper water with scale differences of gas production and gas flow rate.

## Determination of the pH of the hypersaline Dead Sea brine and its mixtures

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The hypersaline Dead Sea and its predecessor, last glacial Lake Lisan, precipitated during most of their geological history sequences of seasonal aragonite laminae. The seasonality in aragonite deposition from the Ca-chloride brine is attributed to supersaturation induced by mixing of the bicarbonate rich runoff water with the Ca-rich lake brine. In order to describe the kinetics and thermodynamics of aragonite precipitation in this unique system, the pH, which is a major variable controlling the carbonate system speciation in the brine and the saturation state of carbonate minerals, must be determined precisely in the Dead Sea brine and its mixtures. The conventional pH measurement is based on the assumption of similar ionic strength of the tested solution and the buffers used for the calibration of the combination electrode. This implies that the potential of the liquid junction between the electrode and the standard is similar to the liquid junction developed when measuring the unknown sample. However, when deploying the conventional pH combination glass electrode in hypersaline brine this assumption can no longer be made. In order to establish the pH of the Dead Sea brine and verify the accuracy of a combination electrode in such high ionic solution, the pH of the Dead Sea brines and its mixtures with deionized water was determined using two ion selective electrodes, ISE. This liquid-junction-free cell consisted of a pH glass electrode (Orion 81-01) and Chloride ISE (Orion 9417). The voltage of the ISEs cell is proportional to the log activities product of Hydrogen ion (pH) and Chloride ion (pCl). The calibration curve was prepared by measuring the ISEs cell voltage per incremental addition of 32% HCl beyond the buffer capacity of the solution. Chloride activity was calculated using the Pitzer database and MacInnes convention using PHREEQC. The pH value of the brine and mixtures were derived by measuring the cell voltage, their major ion compositions and using a calibration curve based on 28 titrations. Simultaneous measurements of pH by the ISEs and a standard combination pH glass electrode (Orion 81-03, calibrated with low ionic strength buffers) were conducted. The values derived in both methods are linearly correlated with respect to the brine's ionic strength. Hence, by applying appropriate correction factor it is possible to use a standard combined pH electrode to measure the pH of high ionic strength solutions such as the Dead Sea brine. The pH of the surface brine of the Dead Sea was determined to be 6.28.

## Syn-Variscan anorogenic volcanism in northern Gondwana: SIMS U-Pb ages of the Gevim quartz porphyry (Helez deep – 1A borehole)

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Gevim quartz porphyry (Druckman, 1984) is the name given to a 200 m thick section of felsic volcanic rocks that was drilled close to the bottom of the Helez Deep 1A borehole. The volcanic rocks consist of feldspar and quartz phenocrysts embedded in a very fine crystalline groundmass. It overlies the Neoproterozoic Dorot Schist and is overlain by the Early Triassic Karmia calcareous shales (Segev and Eshet, 2003). Previous Rb-Sr whole rock isochron age of  $275 \pm 47$  Ma was interpreted as the age of volcanism and considered as recording an Early Permian commencement of rifting-related magmatism in the Levant margins (Segev and Eshet, 2003). Here we use SIMS in-situ U-Pb dating of zircons separated from rock cuttings of 4 depth intervals to precisely and reliably determine the crystallization age of the Gevim quartz porphyry. Zircons of the two deeper samples yield concordant ages of  $353 \pm 1$  and  $345 \pm 1$ , whereas for the two shallower samples 350 and 355 Ma discordia intercept ages with an order of magnitude larger errors were calculated. Our new U-Pb zircon age of the Gevim quartz-porphyry,  $354\text{--}344$  Ma, shows that the magmatic crystallization of the felsic volcanic rocks occurred at Early Carboniferous times. Whereas separated zircon is fresh and idiomorphic, feldspar and micas, the major Rb carriers in felsic igneous rocks, hardly survived. The younger Rb-Sr age is probably the result of either partial or full resetting of the radiometric clocks by hydrothermal alteration. The Gevim felsic volcanism occurred  $\geq 90$  m.y. prior to the earliest evidence of differential block motions, controlled by normal faults that are sub-parallel to the present Israeli coast (Anisian). The Gevim quartz porphyry is thus totally unrelated to the Permian-Early Mesozoic rifting that led to the formation of the Neo-Tethyan Eastern Mediterranean basin. Its geodynamic significance should be sought with an entirely different context: the Palaeozoic epirogenic movements of northern Gondwana. This is the first discovery of Early Carboniferous volcanism in northern Africa and Arabia, however it coincides in time and location with steep crustal thermal gradients and regional uplift and erosion in the Levant (the Helez Geanticline). REE patterns of the dated zircons indicate within plate 'A-type' granite affinity. The geodynamic setting of volcanism is thus suggested to be extensional rather than of Variscan compression, possibly related to rifting and detachment of Gondwanian terranes that were eventually incorporated to the Variscan orogeny.

## Evidence of the Caesarea Maritima 749 AD Tsunami? Or perhaps the case of the tsunami-tinted glasses...

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As of 2011, despite more than 20 tsunamis listed in earthquake catalogues of the region for the past 2500 years, Caesarea alone has presented published physical evidence for any of those events. In the wake of the record-breaking 2004 Indian Ocean tsunami and the Tohoku, Japan tsunami of 2011, the number of studies describing post-event deposits and the alterations recognized along the landscape solidly outnumbers the entire body of literature that was available previously. The field of tsunami research has never before had such a rich range of studies to refer to regarding the signature left behind in a tsunami's wake. These modern analogs are priceless as a means to better interpret ancient sedimentological deposits. Caesarea is an ideal case study for investigating the presence of ancient tsunami deposits, as it is referred to by name in association with multiple events in the historic record (e.g. 92 BC, 115 AD, 551 AD, 749 AD, and 1202 AD). However, with a few notable exceptions, past archaeologists excavating the site typically discarded the 'tsunami explanation' when they encountered anomalous marine horizons in terrestrial contexts, in favor of anthropogenic causes. Today, armed with a more extensive understanding of how to identify and differentiate a tsunami deposit within terrestrial stratigraphy, and the added reinforcement of independent geoarchaeological evidence offshore, it is pertinent to return to the excavation reports and reconsider the evidence. A reevaluation of stratified deposits unearthed at Caesarea over the past 40 years indicates the presence of abundant material traces of the 749 AD event described in historical texts. Here, the summary of that evidence and its previous interpretations will be presented and evaluated in the context of recent advances in tsunami sedimentological research. The issue raised in this study is whether tsunami deposits are being recognized more readily today as a result of zealous over-interpretation of anomalous horizons as tsunami-derived, or whether, in fact, previously tsunami deposits were grossly under-reported.

## Assessing the mobility of trace elements in oil shales based on their distribution among the rock solid fractions

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Organic-rich rocks are often enriched in various trace elements as in the case of the Israeli oil shales. In the present work, the trace element contents in oil shales from five different Israeli deposits, were found to vary over a large range as follows: Be, Cd, Co, Cs, Pb, Sb, and Th are present in low concentrations, up to a few ppm; As, B, Ce, La, Li, Mo, Rb, Se and U are present in concentrations between 10 and 30 ppm; Ba, Cr, Cu, Mn, Ni, V and Zn are present in concentrations of several tens of ppm up to about 300 ppm; and Sr and Ti are present in concentrations of hundreds of ppm up to ~1.5 thousand ppm. However, these total contents are not necessarily leachable thus may have no potential effect on the environment. The mobility of the various elements and their potential migration to groundwater depend on the manner in which they are bound to the rock. The present study offers a novel approach to evaluate the trace elements' mobility in oil shales by adopting a selective sequential extraction (SSE) procedure, which enables us to understand the trace element associations to the solid fractions. The applied SSE was adjusted to organic-rich carbonates and designed to distinguish between five fractions: a. soluble and exchangeable; b. carbonates; c. phosphates; d. organic matter; and e. insoluble residue which contains mainly clays. Using the SSE procedure it was found that substantial amounts of the elements Al, Si, K, Co, Cs, Rb, Ti, Fe, Mg, B, Ba, Ce, Cr, Cu, La, Li, Mn, Pb, Sb, Th and V remained in the insoluble residue fraction, probably because they are bound to the clay minerals. These elements are not labile and are not expected to be released from the rock, even as a result of pyrolysis or interactions with acid solutions. The elements that are bound to the carbonate, phosphate and organic matter fractions can potentially be released to the environment, depending on how the pyrolysis process affects these fractions. Special attention should be given to the elements that to a large extent are bound to the organic matter fraction, including S, B, Ce, Cu, La, Mo, Se, Th and U. These elements are expected to be released from the organic matter as a result of the pyrolysis process. The elements, which were extracted in a large extent in the carbonate fraction, are Ca, Sr, Cd, Mn, Ni, Pb and Zn while in the phosphate fraction mainly P was extracted but also Mg, As, La and U. The release of the above elements and their behavior following the pyrolysis process should be further investigated.

## Combining Spectral Ratio from Ambient Noise with the Multichannel Analysis of Surface Waves Method to Map Subsurface: Test in the Dead Sea Area

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Recent earthquakes have demonstrated that a-priori estimation of possible site effects has become a major challenge for reliable evaluation of seismic hazards. The prediction of site response to earthquakes should be based on analytical models used to calculate expected site-specific ground motions. These computations require knowledge of the subsurface geological structure in terms of shear wave velocity ( $V_s$ ) profile down to hard bedrock. In the last decade, the Geophysical Institute of Israel used horizontal-to-vertical spectral ratios of ambient noise (HVSr) supplemented by the  $V_s$  from conventional refraction surveys. However, refraction surveys are a quite difficult and expensive way to extract  $V_s$  profiles. Combination of Multichannel Analysis of Surface Waves (MASW) and HVSr methods, which are both based on ambient noise measurements, might be a valuable alternative. A test of active and passive MASW together with microtremor HVSr method was conducted at Mineral Beach along the Dead Sea. This site has been thoroughly investigated by different methods, such as boreholes, seismic refraction etc. The HVSr method was conducted at two locations. At the first one, where no salt layer was detected by geophysical methods, HVSr shows absence of resonance frequency, while at the site with two salt layers at different depths, HVSr yields two clear peaks at frequencies of 0.9 Hz and 3.5 Hz indicating two strong impedance contrasts. Direct use of  $V_s$  obtained from MASW for calculating analytical models yields a good fit with the second (high frequency) peak of the experimental function. The depth of the shallow salt layer is confirmed by borehole data. The depth of the deeper layer was estimated using an optimization procedure taking into account its predefined  $V_s$ . Our results suggest MASW and HVSr surface acquisition methods can both be appropriate choices for estimating S-wave velocity and can be complementary to each other for mapping subsurface to depth beyond the capabilities of refraction surveys and boreholes. We plan to use this approach to delineate salt layers in areas in the Dead Sea where sinkholes develop, especially at sites not accessible for conventional geophysical survey.

## Transgressive Coastal Erosion by Short-Duration, Modern Dead Sea Lake Level Rises

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Coastal erosion is a global challenge driven by sea level rise and possibly enhanced as a result of global warming. In the Dead Sea, lake level changes provide natural laboratory analogues to study the impacts of processes such as wave action and lake level rise on coastal erosion. Furthermore, the last 50-years water level drop of the Dead Sea was counteracted by individual 1-2 years of lake level rise. We use these rises and the more common wave activity to understand the magnitude of coastal transgressive erosion as an analogue to similar processes worldwide. This research is also designed to assist in determining magnitude, geometry, and rates of coastal erosion expected to arise from planned stabilization and possible rising of Dead Sea levels by one of the proposed canals. Such renewed lake level rise is not a simple reversal of the current trend of lake level drop and may cause further damage along the shores of the lake. Lake-level drop follows, in general, the pre-existing bathymetry, but lake-level rise erodes laterally to reduce this steep exhumed bathymetry. As a result of such transgressive erosion, prevailing shore conditions prior to last decades of level drop may not be re-established as expected. We emphasize that coastal erosion during fast water-level drop is fundamentally different than coastal erosion during lake level rise. In this context, examination of the effects of modern, historical and pre-historical lake-level rises along the Dead Sea shores provides valuable insights into the magnitude of erosion that can take place in coastal environments during sea-level rises, worldwide. We analyzed the effects of lake-level changes and wave action through high-resolution (0.5 m/pixel) airborne LiDAR data and monthly ground LiDAR scan (~5 cm/pixel) in two common environments along the western Dead Sea shores represented by the coarse-clastic, steep delta front of Nahal Darga, and the mudflat of Mineral Beach. Initial results indicate the importance of wind velocity and direction, storm and water-level duration, lithology and shore aspect in predicting the potential effect of sea-level rise in such environments.

## Resolving the gap between laboratory and field rates of weathering

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The rate of minerals' weathering is a key factor in many environmental problems such as the relationship between silicate weathering and global climate over geological timescales, the availability of inorganic nutrients in soils, geological carbon sequestration, global geochemical cycles, safety of radioactive waste repositories, impacts of acid mine drainage and neutralization of acid precipitation in watersheds, release of toxic elements to soils and to the hydrocycle, and the distribution of porosity and permeability in hydrocarbon reservoir rocks. Weathering rates of silicate minerals observed in the laboratory are in general up to five orders of magnitude higher than those inferred from field studies. The many differences between experimental conditions in the laboratory and natural conditions in the field have been thoroughly discussed in previous studies, but the gap was never fully resolved. For the first time, this study is using a novel method to determine dissolution rates in a single point batch experiment by measuring the change of silicon stable isotopes ratio of a spiked solution with time. The novel silicon isotope ratio method is used in the present study to measure weathering rates of feldspar under close-to-natural conditions. It is for the first time that albite dissolution rate (or any silicate mineral) is described as a function of deviation from equilibrium under ambient temperature and circum neutral pH. The results confirm the extrapolation of high temperature data and fully resolved the gap between laboratory measurements and field estimates. The agreement between the confirmed rate law and the field data indicates that the extensive debate on the gap between dissolution rates determined using laboratory experiments and those using field observation reflects the so far inability to measure the dissolution rates under typical field conditions, using standard laboratory experiments.

## Intense salt deformation in the Levant Basin in the middle of the Messinian Salinity Crisis

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While numerous studies have shown that salt related deformation in the Levant Basin began in the Late Pliocene or Early Pleistocene, here we show that the first salt related deformation event occurred 3-4 myr earlier, in the middle of the Messinian Salinity Crisis. Considering that the entire crisis lasted only about 600 kyr and that halite deposition in the deep basin may have lasted only ~70 kyr, this deformation event must have been very short. At some point after deposition of nearly half of the evaporitic sequence, the upper 200 m thick clastic-rich layer glided downdip and formed a series of steep contractional ridges on the deep basin floor. However, unlike the recent salt motion, which is derived from northwestward tilting of the Levant continental margin towards the Cyprus Arc and by basinward progradation of the Nile-derived overburden, the short intra-Messinian deformation event is enigmatic. It predates the Nile-derived overburden and its direction does not match northwestward tilting. We postulate that it may reflect the uplift of the Carmel block northeast of the study area and possibly of a larger region of the north Levant coast.

## Understanding depositional processes of terrigenous sediments from flash-floods and mass-wasting events in the Dead Sea

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Continental archives such as interplate lacustrine sedimentary basins provide an excellent source of data for studying regional paleo-climate, paleo-seismicity and paleo-environmental changes. Such is the case for the sediments that were deposited in the Dead Sea basin, a tectonically active pull-apart structure along the Dead Sea fault (DSF). This elongated basin is characterized by steep slopes and a deep and flat basin-floor, which are constantly shaped by seismicity and climate through time. The nature of the sedimentary record in the Dead Sea basin responds to changes in the controlling forces. The aim of this study is to understand depositional processes of terrigenous material in the Dead Sea basin using core segments recovered during the December 2010 – March 2011, ICDP coring campaign in the Dead Sea. The 460 m long core at ~300 m water depth in the central part of the Dead Sea, recovered sediments that comprise of fine laminated intercalations of aragonite or calcite with detritus, evaporitic layers and thick clay-silt homogeneous layers (cm to tens of cm thick). Laminated and evaporitic sequences are believed to be deposited under stable lake conditions, however, homogeneous layers represent short-term to instantaneous sediment mass-transport events, possibly triggered by slope instability or variability in the local hydrological regime. The homogeneous layers were catalogued into different types according to visible differences in the internal sedimentological characteristics such as grading, color change and the sediment defining the top and base of each interval. Finally six intervals from the Ze'elim formation, seven from the Lisan formation and four from Samra and Amora were sampled at 1 cm resolution. The samples were analyzed using grain size, XRD, magnetic susceptibility and TOC measurements. While grain size measurements immediately represent the expected trend of fining upwards in these intervals, as seen in mass-transport deposits elsewhere, other measurements such as magnetic susceptibility and XRF require more attention when interpreted. We thus suggest that comprehensive sedimentological characterization as presented in this study should be a compulsive tool in understanding sediment transport processes prior to further possible climate or tectonic interpretation.

## The $^{87}\text{Sr}/^{86}\text{Sr}$ Ratios of Calcite and Insoluble Fractions in Oil Shales; Sr Isotope Stratigraphy and Provenance

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Oil shales in Israel are composed of four main components; phosphate, carbonate, organic matter, and detritus (mainly Al-Silicates). These components can be separated using sequential extraction method and thus enable to address several important questions amongst are (1) their age and (2) their detritus origin. In Israel, oil shales are confined to distinct basins some are exposed while others are found in drill holes. The known assigned age for the analyzed oil shale sequence is based on their stratigraphic position (Bio-Zone) and is Campanian to Maastrichtian age. In this study, we chose to address the two above questions using the  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios measured on both the carbonate and the insoluble residue fractions. The age question is addressed using the Sr ratio stratigraphy, which is based upon the global change in marine water  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio dictated by constant mixture between the riverine Sr input and hydrothermal exchange in mid-ocean ridges. In the studied samples, the absence of dolomite suggests that the associated calcite did not undergo significant alteration and therefore may reflect the isotopic composition of Sr in the ocean water at the time of its deposition. The numerical Sr ages were calculated using [1] and results show that the stratigraphic age determined from the carbonate fraction is in good agreement with the assigned bio-stratigraphic age (68-74Ma). In addition, no correlation was found between the  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of the carbonate fraction and that of the insoluble residue, which strengthens their numeric Sr stratigraphic age. The  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of the insoluble residue should reflect the source of detritus transported to these basins and may shed light on their provenance. It varies and is correlated with Sr concentration. Our data indicate that the source of the Sr is derived from a mixture of two end-members, which are likely to be biogenic and magmatic  $\text{PO}_4$ -minerals. Indeed there is a correlation between Sr, Ca and P concentrations. These preliminary results indicate that the  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio in mono phase separates has the potential of determining numerical age and may shed light on different sources of detritus.

[1] McArthur, Howarth & Bailey, (2001). *Journal of Geology* 109, 155–169. (LOWESS V5).

## Archaeological destruction layers – a key to high accuracy chronostratigraphy

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Astride the Dead Sea Fault and situated at the crossroads of empires, religions and cultures, the Levant contains many ancient archaeological sites dating from before the dawn of history to modern times. Many sites contain destruction layers perhaps caused by earthquakes and conquests. These layers, if well dated, can serve as chronostratigraphic markers bearing valuable seismic and geo-magnetic data. These data can then be used for constraining dates of other sites or for testing correlations between stratigraphic layers. Our work focuses on well dated destruction layers in archaeological sites that suffered significant earthquake damage. High resolution geometrical measurements of the ruins, made by a ground based laser scanner, enable creating 3D models of the damage structures. These, when compared to theoretical pre-destruction models, can characterize the damage inflicted on the site and provide information about the damaging earthquakes. A 3D model was created for Khirbat al-Minya, an Umayyad palace built on the northwest shore of the Sea of Galilee in the early 8th century CE and was severely damaged by earthquakes. In addition, destruction layers can store the direction and intensity of the geo-magnetic field prevalent on the destruction date. Archaeological materials such as pottery artifacts and clay bricks, heated above the Curie temperature by fires triggered by an earthquake or set by a conquering army, gain a magnetic vector parallel to the ambient prevailing at that time. If the destruction layer was sealed by debris or covering layers, artifacts can be found in situ and sampled as oriented, preserving the direction of the magnetic vector. We focus mainly on household cooking stoves (tabuns) found within destruction layers. Tabuns, and other heating facilities, are ideal for paleo-magnetic studies, preserving the magnetic vector of the last time they were heated and usually not moved after construction. Thus they are useful even in the absence of conflagrations. Magnetic samples were collected from several layers of Tel Megiddo and at rescue excavations near the modern town of Yavne. Preliminary analysis suggests that the artifacts have preserved the magnetic field in high

precision. This information is crucial for research of the Earth paleo-magnetic field. In addition, knowing the changes in the direction and intensity of the archaeo-magnetic field in adequate resolutions may enable future archaeological researchers to constrain conventional dating by an independent measurement.

## The origin of *Spirula spirula*, Linne 1758

Heyfetz E. O.

*Spirula* is the relict cephalopod with an internal spiral shell whose whorls are free. According to the currently accepted version, *Spirula* is descendant of the belemnite-like forms, with a bent shell and related to cuttlefishes. These forms are rare fossils, since their guard is composed of unstable aragonite, instead of the calcite guard of the true belemnites. Such reconstruction is based on the similarity of the supposed ancestral forms with belemnites. Meanwhile due to the common evolutionary tendency, the internal shell should be reduced – and not produce the spiral. Morphological analysis of *Belemnoseina* shows that the less bent forms came from the more bent ones and that the latter should originate from animals with the spiral shell. The shell of *Spirula* does not bear remnants of a guard, whereas on the internal side (opposite to the guard) the author found a pair of keels, going through the juvenile chambers. There is a kind of a case, in which previous whorls were placed. So, *Spirula* comes from the form not with bent, but with densely coiled spiral shells, i. e. from typical ammonites. The opposite orientation of *Spirula* shell relative to that of typical ammonites is explained by re-distribution of buoyancy. The fragile shell of *Spirula* is rarely preserved in the fossil record; the earliest specimens are found in the Miocene. Analysis of the geographic distribution of *Spirula* indicates that the species originated between the lower and upper Jurassic, i. e. it was contemporary with typical ammonites. In accordance with the theory of evolution of passive means of floatation, *Spirula* is considered to be a passive animal, hanging in the water column head down contradictory to its morphology, in particular, to the position of the luminous organ, serving for the distant connection. Turning to the literature, the author found that in the report of the Bruun expedition that scientists omitted a complete paragraph of straight observations on *Spirula* providing evidence that the latter is a perfect active swimmer. Hence, the theory influences perception of the facts.

## 800 meters inside the earth - observations of seismic activity in the Dead Sea basin using borehole seismometer

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Seismological measurements, conducted at great depths of several hundred of meters or even a few km, can provide useful information that one cannot get while conducting the measurements on the surface. We take advantage of the Masada Deep borehole, an abandoned oil well, for the installation of a seismometer at a large depth of 800 m. Until now no such station has operated in Israel. Seismological observations since 1983, using permanent and portable stations, revealed earthquake activity along the fault and its proximity, which is in good agreement with geological observations of young faulting age (>KY 30). The operation of such station will enrich the seismological database with high quality data. The study has a few goals: 1) improving the detection capabilities of small earthquakes in the Dead Sea basin; 2) improving characterization of seismic activity in the Dead Sea basin; 3) better identification of seismic activity on the fault and observe earthquake nucleation and rupture processes in the near field; 4) searching for periodicity of seismic activity (if exists); 5) better understanding of the short-term processes and conditions near the fault, prior and shortly after the occurrence of an earthquake; 6) extending the Gutenberg-Richter of frequency-magnitude relationship of earthquakes into smaller magnitudes below the threshold of the ISN catalog. In April 2012 the plug of Masada borehole was drilled and later a depth check was conducted by lowering a heavy weight, which simulated the seismometer at large depth. The borehole seismometer was installed in Dec. 2012. We present seismic observations of small earthquakes conducted at a depth of 800 m, many of them were not recorded by the Israel Seismic Network.

## Difficulties in geotechnical study for tunnel construction: rock, natural reserve, graves – how can we overcome? The Rosh Ha'ayin case study

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The construction plans of the new neighbourhoods of Rosh Ha'ayin include 3 road tunnels. They penetrate through a hill in the vicinity of the "Migdal Tzedeq" archaeological site, which consists also of ancient graves and a natural reserve. The hill is composed of the Bina Fm. limestone undulating layers, up to 2 m thick. Relicts of abandoned quarries expose the rock face in 10-30 m high cliffs around the hill. The onsite situation prevented drilling along the exact path of the tunnels. Therefore, drill core Information and rock exposures from a broader area of the project, were used to extrapolate rock mass condition in the tunnels area. More drills penetrating the tunnels' paths would permit the use of less conservative parameters for the rock mass classification. The variability in the joints conditions and also common but random rock weakening phenomena (e.g. karst), has made it difficult to estimate specific rock mass quality parameters affecting the tunnels stability. Joint measurements were plotted on Rose Diagrams for different exposed faces. Parts of the joints appearing on the exposed cliffs are linked to explosions during the time of quarrying. Two different strain fields were detected by "slick and slide" striations. It was noticed that RMR and Q parameters differ significantly when applying the characteristics of the joints conditions. When the tunnels will be excavated, we shall find out if our educated assumption concerning the rock mass conditions made using information outside of the tunnels paths is in accordance with the actual condition of the rock in the tunnels. The estimated values of RMR and Q classification differ from one another, suggesting "Fair Rock" and "poor Rock" classes respectively. A major question - which classification system is better fitted for tunnelling design when crossing the carbonate layers rock so common in Israel? Should we develop a specific system?

## Natural Hazards in Israel, 1948-2013: A Temporal and Spatial Analysis

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The impact of natural hazards on the Earth's population has increased several folds in recent decades. The aim of this study is to review the natural hazards- earthquakes, floods, landslides, droughts and forest fires- that occurred in Israel since the establishment of the State until today, a period of 65 years. No earthquake occurred in the studied period with a magnitude above 5.5 within the limits of Israel. Floods are the cause of most of human victims and economic losses. The major events in the Mediterranean climate region of Israel were the 1969 floods in Northern Israel, the 1992 affecting mainly the coastal areas, the 2003 and recently the 2013 floods. In the southern Negev desert area exceptional floods were registered since the new century in 2004, 2006, 2007, 2012 and 2013 causing considerable economic losses. Four major prolonged drought periods occurred in the 65 year period. 1998 to 2001 was the most critical for the last 140 years, concluded from long-term rainfall in northern Israel and Beirut. The vulnerability to drought is increasing as growing of population intensifies the pressure on water resources. Forest fires affects forest ecosystems causing major changes in the environment, some of them irreversible processes like loss of soil. Frequency of fires increased in last decades. The single largest disaster event was the 2010 forest fire in the Carmel with 44 victims. Sea storms caused economic and archaeological damage along the dense populated coastal area. The December 2010 was the major event in last decades. Natural hazards in Israel are accentuated by man's activities, increasing the vulnerability of the environment. The meteorological related hazards, like floods, droughts and forest fires, are the processes that cause the most human and economic losses. A future eventual climatic global change is likely to accentuate the effects of catastrophic events. A change in rainfall patterns toward more extreme events, i.e. higher intensities or more prolonged and frequent droughts, may induce a larger frequency of floods, droughts and forest fires. Geomorphic processes like floods or landslides have a threshold value, and as population and built-up areas expand the frequency of encounter with natural processes and environmental vulnerability may increase, even without a change in the frequency of hazards.

## Anthropo-pedogenesis in a Calcrete Profile: Case Study from the Binyanei Ha'Uma Site, Jerusalem

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Calcretisation in human dominated environments can be affected by anthropo-pedogenesis. Such is the case with a calcrete profile at the Binyanei Ha'Uma site in Jerusalem. This profile developed in a host regolith of a dedolomitised upper Weradim Formation and a montmorillonitic, reddish brown, Terra Rossa soil. Based on previous studies, this calcretisation corresponds to a late Pliocene to Holocene multiphased regional event. The earliest known inhabitation of the site was during the Iron Age II (late 8th c. to early 6th c. BC), marking the possible initiation of anthropo-pedogenesis. This study included field observations and micromorphological analysis of 10 thin sections and more than 40 SEM samples of the calcrete profile, indicating six, partly concurrent, genetic phases: (1) Dedolomitisation of the upper Weradim Formation, evident from reworked dolomite crystals in a micritic matrix, (2) Normal faulting, which juxtaposed dolomite of the lower Weradim Formation with the dedolomitised upper Weradim Formation, (3) Pedogenesis, accompanied by massive aeolian (and possibly fluvial) montmorillonite input, as evident from intrusive clay pedofeatures, (4) Montmorillonisation of the upper Weradim Formation, reducing its hydraulic conductivity, (5) Formation of karstic voids and further pedogenesis under different pH conditions, as evident from impregnative nodules of iron and clay, and strong Fe-hydroxide stained clay coatings, and (6) calcretisation, showing micromass of micritic cement with crystallitic b-fabric, calcite intrusive pedofeatures of microsparite, and sparite infillings with crystal intergrowths. The resulting profile consists of ~3 m of differentiated morphology, including fragmental-chalky, powdery, sub-hardpan intergrading to hardpan, rhizcretionary, and laminar calcrete. The factors and timeframe for the anthropo-pedogenesis are interpreted mainly from the archaeological findings, revealing continuous inhabitation history of the site. Nevertheless, the major anthropogenic affect at the site occurred during the Roman period, from ~70-250 AD, when the Tenth Roman legion maintained a depot for producing pottery, water-pipes, bricks and tiles, alongside agricultural cultivation. Upon the departure of the legion, quarried subsoil rooms were filled with limy (CaO-related) carbonatic waste, which also covered the surface of the site. This event had a significant anthropogenic enhancement of calcium carbonate (CaCO<sub>3</sub>) input to the subsoil, as indicated by calcitic overprinting of anthropogenic features. I therefore suggest an anthropo-calcretisation phase which is controlled by two main anthropo-pedogenic pathways: (1) calcium carbonate (CaCO<sub>3</sub>) and

calcium hydroxide  $[Ca(OH)_2]$  infiltration from limy industrial materials into the soil, and (2) rhizospheric carbon dioxide ( $CO_2$ ) respiration of agricultural flora. This study presents an independent approach to archaeological excavation in calcretised areas. Anthropo-pedogenesis results from human activities, such as the production of pottery, construction materials, and agriculture, and can be observed by micromorphological methods. Therefore, the presence of calcrete in archaeological sites should be carefully considered in the context of a material culture, especially when common anthropogenic remains are scarce.

## Reconstructing the shoreline and climate of Vista Alegre, Quintana Roo, Mexico

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The environmental and morphological history of the Maya site 'Vista Alegre', is being investigated by a diverse team within a larger multidisciplinary effort called the Costa Escondida Project. The project's main goals are to learn how the ancient inhabitants of the site adapted to the coastal environment, and the integration of this coastal site into broader maritime trade routes. Vista Alegre is located in a saltwater marsh in the northeastern part of the Yucatan peninsula, in the modern state of Quintana Roo, Mexico. The site is well protected from typical storms and is favorably situated near the meeting point of the Caribbean Sea and Atlantic Ocean. While the general topography of the site is quite flat, a pyramid in the central portion of the site provides a strategic lookout to observe coastal boat traffic and may have served as a 'mirador' (lookout) as well as a sacred locale. Ancient coastal traders that were traveling the trade routes around the peninsula in large dugout canoes may have been attracted to the site due to its protected location. They would have docked at the site, perhaps in artificially created proto-harbors. The specific portion of the research presented here defines the changes in terms of geomorphology and climate on the site during the last 2-3000 years. This study helps complete our understanding of the sites possible functions, the environmental problems the local inhabitants had to contend with, and the harboring locations that may have existed at the site. While reconstructing the ancient shore line, the weather patterns and climate changes we will address a range of questions such as: finding hurricane proxies in the sediment, locating underwater manmade seafaring artifacts and facilities, possibilities of economic opportunities for the inhabitants in the past and potable water sources on site. The multiproxy analyses that are being used to address the research questions include coring, LOL, grain size, micropaleontology, dating, geochemistry, geomorphology and seismic survey.

## Interconnected Stylolite Networks: Field observations, characterization, and modeling

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Stylolites are rough surfaces formed by localized rock dissolution. They often appear in large populations, with one of the most common morphologies being Inter-Connected Stylolite Networks (ICSN). In ICSNs, stylolites are connected to one another by anastomosing or via veins and fractures. One can trace along an ICSN, from any side of the rock to any other side, since in ICSN stylolitic surfaces are fully connected (percolating) in 3 dimensions. The morphology of ICSNs has not been quantified before, because of the difficulty in characterizing interconnected features. Yet, it is important to quantify ICSN at small and large scales because pressure solution creep, both in its diffuse morphology and in its localized stylolitic morphology, has been recognized as one of the most significant and widespread rock deformation mechanisms in the upper crust, with important implications for strain and fluid flow. We propose a new method to characterize such ICSN networks, focusing on “islands”, the intact areas caught between the connecting stylolitic surfaces (also called “microlithons”). Islands appear on all scales, from a few mms to a few meters. In order to quantify the island distribution and dimensions in ICSN, we mapped an in-situ polished outcrop located in abandoned quarry north to Mizpe Ramon. We characterize the dimensions of islands using bounding boxes. Our analysis shows a power-law relationship between the horizontal and vertical dimensions of islands, with a scaling exponent 0.67. Next, we simulate the formation of ICSN via the merging of long rough stylolite surfaces, capturing intact islands in the process. The simulations produce artificial ICSN that allow us to check the hypothesis that ICSN form by merging of long stylolites. In addition, simulations also provide a unique opportunity for investigating the complexity of statistical properties of anastomosing morphology, by determining the dependency of island scaling exponent on the roughness and spacing of the original stylolitic surfaces before they merged.

## The significance of the finding of diluted seawater in the Yoqne'am 7 borehole, east of the regional groundwater divide

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Yoqne'am 7 borehole was recently drilled to the Judea Group Aquifer eastward of the regional groundwater divide, where the aquifer drains to the eastern Rift base level. An interface between the saline water body and the overlying fresh water body was detected at a depth of 120 to 220 m below sea level. The saline water body has a geochemical signature of diluted seawater based on  $rNa/rCl$  and  $Cl/Br$  ratios as well as on  $\delta^{18}O$  composition.

Previously, a current subsurface seawater encroachment was proposed across the regional divide all the way from the Mediterranean Sea to the eastern Rift base level in the northern domain of Mount Carmel and the northern valleys. This was mainly based on the elevation difference between both base levels. On the other hand other studies interpreted the existing brackish water or water with salinities close to that of seawater in this domain as a dilution product of calcium-chloride brines at depth by fresh water.

Subsequently, boreholes drilled to the Judea Group Aquifer in the northern part of the Yarqon-Taninim basin (upto some 10 km east of the shoreline), already encountered diluted seawater according to their geochemical signatures. The fresh / saline water interface was detected there at depths around 900 m below sea level.

A deep TDEM traverse that was executed prior to the drilling of Yoqne'am 7 borehole and passing close to its location managed to show the west-east rising and subsequent declining of the interface across the divide as was later on evidenced in the Yoqne'am 7 borehole.

The findings in the Yoqne'am 7 borehole apparently support the previously proposed assumption of current seawater encroachment across the regional groundwater divide to the eastern Rift base level.

## 50,000 Year Seismically-Triggered Turbidite Record from Dead Sea Deep Core

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A paleoseismic record of the Dead Sea fault from the Last-Glacial period is revealed in Lake Lisan sediments from the Dead Sea's depocenter. Core 5017-1-A was drilled during winter 2010/2011 and is the deepest of the cores from this ICDP campaign (465 m). The sediments are mostly alternating aragonite and silty-clayey detritus (aad), laminated detritus (ld), gypsum layers and mass-movement sequences. The aad, ld, and gypsum are well known from the Lisan Fm. outcrops from the lake margin, while the mass-movement sediments are unique to the deeper environment. Deformation features found in the core include: brittle deformations such as intraclast breccias, small faults, discontinuous laminae; ductile deformations such as folded and smeared laminae; mass-movement sedimentation such as turbidites and homogenites. The turbidites are ubiquitous and can be recognized by a coarse (sandy) base of a few millimeters to a few centimeters below a quasi-homogeneous layer of up to more than a meter. Huge (>1 m) folds and breccias are more common in the middle part of the section. An enormous quantity of sediment is added to this deep-lake section due to these events. The Lisan period (70-14 ka) in the deep core is represented by about 115 m of sediment thickness, ~3 times thicker than the lake margin outcrops. The sedimentation rate of the Lisan period and of the core in general is about 2m/1,000 yr. Preliminary results suggest that there may be up to an order of magnitude more deformed layers in the core (Lisan Fm.) than during the same time period in the outcropping sections (lake margins). This is probably due to the fact that slumps, slides, brecciation, and turbulent flow from any part of the lake reach the depocenter, where this core was drilled. This may provide a paleoseismic record representing the entire Dead Sea Basin.

## Observation of Local Site Effect of Four Designed Bridges on the Stretch of Road 71 between Afula and Bet Shean.

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During the 1971 San Fernando, California, earthquake ( $M=6.6$ ) seven bridges were completely destroyed and additional 60 structures suffered moderate to extensive damage. The 1989 California ( $M=6.9$ ) earthquake demonstrated importance of providing experimental estimation of local site effect for design of new bridges. The effect of local site conditions has a major role in the shaking levels and hence should be incorporated into seismic hazard estimations, especially when considering the vicinity of the study area to the Dead Sea fault. At the request of Israel National Roads Company Ltd., the GII Seismology Division performed series of measurements and calculations for site response assessment at four bridges to be built on the stretch of the Road 71 between Afula and Bet Shean. As input for site response assessment a 1-D analytical model is used, which should be validated empirically through the detailed seismological survey based on microtremor measurements. Single station microtremor measurements were conducted at 58 points. The results show horizontal-to-vertical spectral ratio (HVSr) peaks in the frequency range 1.5-7 Hz and amplitude level varying from 4 up to 8. We constructed 1-D model of the subsurface, which is consistent with the HVSr measurements by integrating available borehole data, with geological information and the shallow shear-wave velocity profile provided by refraction survey. The results of modeling allow reconstructing geological cross sections at sites of designed bridges. Detailed analysis of the measurement results in combination with other available data show that the fundamental reflector in the study area is the Lower basalt of Miocene age (and not the Cover basalt according to the seismic refraction data) and its depth varies in the range of 15-85 meters.

## Locating the on-land continuation of the submarine Avrona Fault, Eilat

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We aim to contribute for the compilation of the seismic record of the Northern Gulf of Aqaba-Eilat (NGAE) by locating and characterizing the on-land continuation of the active submarine Avrona Fault. It is a segment of the Dead Sea Fault (DSF), located at the transition zone between the deep marine basin of the NGAE and the continental basin of the Arava Valley (Wadi Arava). Its on-land part underlies the Hotels District at the northern beach of Eilat, where seismic deformation was documented after the 1995 Nuweiba earthquake (7.2 Mw). We try to locate the fault on-land and recover its seismic record. The palaeoseismic trench site was selected based on the projection of the trace of the submarine Avrona Fault and analysis of aerial photos from 1945 and 1957 and a Ground Penetrating Radar (GPR) survey. The 1st trench (ET1) revealed liquefaction deformation features, but no fault trace was evident. Trench ET3 revealed both liquefaction features and the fault trace itself. Three distinct units (at depths up to ~1.5 m below surface) with cumulative normal offset of ~50-60 cm were observed. Charcoal samples were located and sampled for <sup>14</sup>C dating. Faulted trench strata are from the top 1.5 m, suggesting the fault is recently active. <sup>14</sup>C Age determination yield age and slip rate constraints of the faulting. Dating of the liquefaction sandblows may correlate to the liquefaction documented after the 1995 earthquake, or to earlier surface rupture. We suggest that the fault located at ET3 is the on-land continuation of the submarine Avrona Fault, an active segment of the Dead Sea Fault, at its transition zone from marine to continental structural framework.

## Earthquake and flashflood markers in core sediments from the Northern Gulf of Aqaba-Eilat

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We aim to contribute to the compilation of the seismic record for the Northern Gulf of Aqaba-Eilat (NGAE), trying to identify and differentiate evidence for depositional mechanisms triggered by seismic activity in the marine sedimentary record. In the presented study, we aim to identify recent (<100 yrs) seismic and flashflood events in the upper sediment from the Northern Gulf of Aqaba-Eilat, as modern analogs for similar events in core sediments from late Pleistocene/Holocene, using high-resolution grain size analysis. Upper sediment (<35 cm) was sampled at specific sites across the deep basin using a multi-corer. Eleven short cores (MC11 1-11) were retrieved from 10 various locations in the NGAE (200-700 mbsl). High resolution granulometry resulted in characterizing typical deposited grain size range, and the identification of anomalous coarse grain events, suggested as evidence for sediment reworking (e.g. slumps and turbidities, possibly induced by seismic or climatic triggers) in 6 of the cores. Comparing these events to recent documented seismic and climatic events will allow identifying the triggers for such sediment transport and discerning earthquakes from flashfloods in the sediment, thus isolating the seismic record. Radiocarbon and <sup>210</sup>Pb dating of these anomalous events in the sediment are currently in process. The spatial distribution of the cores was examined for possible differences in the sedimentary regimes at different locations in the Gulf.

Grain size patterns defined in the short-cores were additionally compared to three already retrieved piston cores available from across the Gulf (MG10 P22, P27 and P29; 150-450 cm long). Due to the nature of piston core retrieval, their top sediment was mixed and resorted and is not usable for record reconstruction. The short cores collected at adjacent sites were used to complement the youngest segment of the piston cores. Comparing MC11 short cores with the top of the MG10 piston cores resulted in differentiating real sediment reworking events in the piston cores from mixing of the top during retrieval. Grain size patterns observed in the short cores were used as modern analogs to trace similar patterns in the piston cores. A pattern of anomalously changing fine-grain to coarser grain sequence, possibly

indicative of flashflood events, was identified both in the short cores and piston cores. This may help to differentiate seismic events from flashflood events in the sedimentary record. Combined with future radiocarbon dating of these events, we expect to contribute to the compilation of the seismic record of the NGAE. In addition, the spatial distribution of the MC11 short cores at which anomalous sediment reworking events were identified, leads to suggest that the northern part of the Eilat sub-basin, between the slope of the Eilat Fault and the canyon at the bottom of the sub-basin, contains more active sedimentary processes than the neighboring Ayla High and the southern part of the Eilat sub-basin.

## Dispersal of flood sediments by turbidity currents at the northern Gulf of Aqaba

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Flash floods that enter the sea through the Arava Valley are the main transportation source for lithogenic sediments and various metals in the northern Gulf of Aqaba (GOA), Eilat. We present new videotaped evidence showing that when entering the GOA the dense flood waters form a hyperpycnal plume that runs as a turbidity current along the seafloor. This plume progresses down the slope extending hundreds of meters or more southwards. For this to occur, sediment concentrations of fine, terrigenous particles should exceed 45g L<sup>-1</sup> thus making the fresh, flood water denser than the encountered seawater. The appearance of a brownish sediment plume around the outlet occurs only hours later, when turbulence raises the fine particles to the surface. Flood events at the northern Gulf of Aqaba occur between several times in a rainy year to once every few years during dry periods. These flood entrainments block the sunlight from days to weeks over large areas of the north beach of Eilat and deposit a muddy layer on the sandy seafloor; a disturbance which is fundamental in shaping this ecosystem e.g. being the likely reason for the absence of coral reefs in this area. Analysis of sediment cores show that most of the deposited flood material off the north beach of Eilat is eventually eroded and transported into greater depths.

## Radium and radon in the Dead Sea hydrological system

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Groundwater concentrations of radionuclides were shown to be significantly affected by water-rock interaction. In particular, radon and radium isotopes are usually enriched in groundwater as a result of their parent nuclides in the host aquifer solids. This study aims to use the Dead Sea hydrological system as a natural field lab for studying the behavior of radon and radium isotopes in a system with a large salinity range, various lithologies and diverse hydrological mechanisms. For this purpose, a detailed survey of the radium and radon sources to the Dead Sea was done. Radium and radon concentrations and isotopic ratios are controlled by the type of the rock (in terms of Th/U ratio), the groundwater age, adsorption of radium and the groundwater flow mechanism. In the Dead Sea periphery, differences in the the Th/U ratio of the aquifer rocks are reflected in groundwater  $^{228}\text{Ra}/^{226}\text{Ra}$  and  $^{224}\text{Ra}/^{223}\text{Ra}$  ratios, with these ratios being significantly higher in the eastern catchment, compared with the western Dead Sea groundwater.  $^{226}\text{Ra}/^{223}\text{Ra}$  and  $^{224}\text{Ra}/^{228}\text{Ra}$  ratios in young groundwater (such as the circulated Dead Sea water) or in recently mixed groundwater (such as in the fresh--saline transition zone or in the Kane and Samar springs) deviate from secular equilibrium while in the older groundwater of Ein Feshkha, Ein Qedem and at the eastern catchment of the Dead Sea, these isotopes are in secular equilibrium. This may suggest a longer period of water--rock interaction.  $^{222}\text{Rn}$  activities are very high in most of the Dead Sea groundwater, and may be in excess of 100% of the  $^{222}\text{Rn}$  produced by the aquifer rocks, suggesting a major contribution by locally adsorbed  $^{226}\text{Ra}$ . The highest activities were found in the thermal brines, both at the east and west of the Dead Sea and in Ein Feshkha. This could be related to an increase in the adsorption of  $^{226}\text{Ra}$  due to the decrease in salinity (mixing of Dead Sea water with spring water) or to the decrease in water temperature during the ascent of thermal brines. The largest variability in each of the groundwater groups around the Dead Sea is due to the adsorption of radium, while the differences between the groups are mainly explained by the differences in the U/Th ratios in the aquifer rocks, flow mechanisms and groundwater age.

## Coastal Paleogeography, as a means for understanding the Bible's landscape

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The bible contains various scenic references describing the geographic position of places or borders. Alas, the landscape nowadays does not always fit the description mentioned in the bible. Paleogeography deals with reconstructing ancient landscapes. It ties between various findings- physical, geological, pre-historical and archeological evidence, a connection which enables a glance to a landscape that no longer exists. The bible describes past landscapes and it is possible that the landscape described in the bible does not fit the current landscape. This might raise questions in the literal reading of the biblical text. This study presents three scenic descriptions from the bible, which are not understandable to the reader regarding current landscape, but can be explained by Paleo-geographical analysis that suggest landscape reformation. The three cases are (1) description of the land allocated to the Zvulun tribe, (2) description of the island of Tyre, and (3) description of a peninsula in northern Dead Sea. The study will also present the Midrash relating to the verse mentioned twice in the book of Amos: "...that calleth for the waters of the sea, and poureth them out upon the face of the earth; HaShem is His name". The Midrash describes two floodings: one in the generation of Enoch and the second in the generation of secession.

## Paleoenvironmental conditions during the Bronze and Iron Ages (~5,000-2,500 YBP) in Lake Kinneret area, based on pollen analysis

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A new pollen analysis was performed on a core drilled at the inner part of Lake Kinneret in 2010. The aim of the study was to reconstruct, in detail, the vegetation, climate and human impact on the environment during the interval of the Bronze and the Iron Ages (~5,000-2,500 YBP). To achieve this goal, high resolution pollen sampling was obtained (sample/~40yrs). The chronological framework was based on radiocarbon dating of short-lived organic material. Since the Early Bronze until the later phase of the Late Bronze (~5,000-3,250 YBP), moderate climate conditions were prevalent in the area. The vegetation was characterized by relatively high frequencies of Mediterranean trees, with the dominance of evergreen oak (*Quercus calliprinos* pollen type), deciduous oak (*Q. ithaburensis* pollen type) pistachios (*Pistacia*) and/or cultivated olives (*Olea europaea*; the olive orchards overtook areas formerly occupied by wild olives and other Mediterranean trees and are therefore also an indicator for the available moisture). Two short dry events dated to ~4,300 YBP and to ~3,950 were identified based on a decrease in both Mediterranean elements and olive percentages. However, the most prolonged dry episode during the Bronze and Iron Ages was dated to ~3,250-3,130 YBP. This pronounced aridness was characterized by the lowest tree percentages throughout the entire sequence. From the archaeological point of view and based on textual evidence, at the later phase of the Late Bronze Age (since ~3,250 YBP) an economical-cultural-political crisis occurred in the Ancient Near East that lasted more than a century. While wetter climate conditions were documented during the Iron Age I (~3,150-2,950 YBP), a slight dryness was observed during the Iron Age II (~2,950-2,500).

## In-Situ Chemical Oxidation (ISCO) Pilot Study for the Remediation of the Coastal Aquifer Contaminated with Chlorinated Hydrocarbons

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As part of ongoing groundwater monitoring, the Department of Water Quality of the Israeli Water Authority (DWQ) identified a number of polluted areas from industrial sources around the Holon Industrial Park that contaminated groundwater and required the closure of production wells. In order to deal with the pollution and evaluate the appropriate method of treatment, the Water Authority selected Ecolog Engineering ltd (Ecolog) services for examining remediation alternatives by constructing a flow and transport model for the investigated area. Ecolog constructed a 3D model for predicting the flow and transport of the pollutants (last updated in 2012). The results of the study showed that the preferred remediation method is in-situ treatment of groundwater at the sources of the pollution. Therefore it was decided to perform an in-situ groundwater remediation pilot at one of the sources of pollution. An in-situ groundwater remediation pilot (pilot) was carried out by Ecolog, with Golder Associates support, at the coastal aquifer in the Holon industrial area. The principle pollutants in the groundwater at the site are trichloroethylene (TCE) and 1,1 dichloroethlyne (1,1 DCE) with concentrations of 2,000-5,000 ppb and 100-500 ppb respectively. The pilot started on 02.09.2012 and over the course of five (5) days, 71 m<sup>3</sup> of a potassium permanganate (KMnO<sub>4</sub>) solution at a concentration of 2,000 mg/l was injected into the aquifer. After a half-day of pumping and recirculation into the aquifer, breakthrough of the KMnO<sub>4</sub> solution was observed in the shallow monitoring wells (T-7 and T-9) 3 m from the injection well. On 16.12.2012 (105 days following the initiation of the pilot), breakthrough of the KMnO<sub>4</sub> solution was observed in the shallow monitoring well (T-10), 7 m' from the injection wells. Trace quantities of KMnO<sub>4</sub> were observed in the deep monitoring well T-6. The groundwater monitoring results three (3) months following the injection, showed that the TCE and 1,1 DCE concentrations decreased by about 97%-99% (in the injection well and shallow monitoring wells at a 3 m' radius). A 90% reduction in TCE and 1,1 DCE was observed in the shallow monitoring well, 7 m' from the injection well.

## Exhumation of Dead Sea bathymetry and the sinuosity increase of its western coastline

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With the fast declining Dead Sea level (-427 m in 2013) in recent years, its western coastline exhibits a large sinuosity increase characterized by numerous narrowly curved bays and pointed and narrow small peninsulas. The high-resolution bathymetry of the Dead Sea (grid size = 5 m; Beaudoin et al. 2011) indicates that these new and common features are the exhumation of the topmost parts of distinct underwater ridges that characterize the Dead Sea's western slope. These topmost ridges and valleys have a common upper altitude of ~415 m and extend down slope, eastward and perpendicular to the shore, some of them extend all the way to the Dead Sea deep. This distinct morphology characterizes the western slopes of the Dead Sea, whereas in the eastern slopes of the lake these features are much less extensive. The western slope is covered by relatively thick late Pleistocene and Holocene sediments. Characterizing these features and identifying their origin are the goals of this study. The Western slope of the Dead Sea has the following features, from top to bottom: (a) an upper exposed coastal plain (altitude ~-400 m) with minor coastline sinuosity (~1.3), (b) steep slope, ~10 degrees, between altitudes of -410 m to -580 m with highest sinuosity (>2), and spacing between ridges is a few hundreds of meters, (c) the lower part of the slope from altitudes of -580 m to -710 m with slope angle ~3 degrees and spacing between ridges is ~1 km, and (d) the practically flat abyssal plains at ~-720 m. Hypotheses for the origin of this morphology include (a) incision by streams during past low sea levels, (b) deposition, (c) tectonic activity, and (d) submarine landslides. Incision by streams is ruled out as most of the underwater valleys have no stream mouth or drainage basin on land. This also rules out deposition. Underwater landslides can explain most of the observed bathymetric morphology, where tectonic activity may trigger them. We propose that the high slope angles of the basin fill sediments, together with the seismically active environment, the high density of the Dead Sea brine, which reduces the effective weight of the sediments, all contribute to the landsliding. Rapid lake level drops in the past could have enhanced landslides by increasing the effective pore pressure as a result of over-consolidation. Submarine landslides and turbidity gravity currents can also explain the flat abyssal plains, which may have developed due to the lateral dispersion of the slope sediments and their flat and probably even re-deposition throughout the deeper parts of the lake.

## Comparison of Mediterranean live and dead benthic mollusca as a proxy for tracking anthropogenic modification

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Shelled mollusks (bivalves, gastropods) are sensitive indicators of seafloor health conditions. Mismatches between the local living mollusk community and the dead molluscan assemblage have been shown to be associated with recent, rapid, anthropogenic changes. This study is aimed at testing for match or mismatch in the coastal community structure of modern (sediment-top) death assemblages vs. live-collected mollusk assemblages, from clean control (PL29) and polluted sites (PL3), near the Shafdan sewage sludge outfall offshore of Palmahim. Seasonal variability in both the polluted and clean stations was captured by box-core sampling in January (winter), May (spring), July (summer) and November (fall) of 2012. Dead and live mollusks were taken from the upper 1.5 cm of the sediments. A vessel-operated dredge was dragged over a distance of 30 m to acquire a larger volume of sediment containing live mollusks. Community structure variables, environmental parameters and BENTIX index are under analysis to define the differences between the live and dead assemblages, within and between sampling stations. To date, winter (Jan) and fall (Nov) 2012 live and dead assemblages from PL3 and PL29 have been analyzed. *Corbula gibba* is the dominant species in nearly all assemblages. Differences in community structure between the live and dead assemblages were unrelated to sampling site or season. The death assemblages in all seasons and stations show high agreement in relative abundance and taxonomic composition. An increase in deposit feeding bivalves is seen in the live assemblages in both stations and seasons. This is mainly caused by the increase in abundance of *Nuculana pella*, bivalve species known to thrive in organic-rich sediments. The ultimate database will include also benthic foraminifera and ostracodes from the same samples. Differing sensitivity of these three calcareous-shelled groups to anthropogenic impact can be used to evaluate environmental change in comparable areas around the Mediterranean.

## Coastal effect on marine TDEM measurements with due regard of the near-shore bathymetry

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Marine time domain electromagnetic (TDEM) broadside Ex-Bz system has been found feasible for detecting sub-seafloor resistive targets in transition zones, where the CSEM method becomes inefficient due to the air-wave phenomenon. The abnormal sensitivity of the system to sub-seafloor resistive structures is caused by the multidimensional resistivity contrast between seawater and submarine sediments that increase the target response under certain geoelectric conditions and transmitter-receiver configurations and offsets. Until now, these conditions were investigated both theoretically and practically for the specific, fairly mild bathymetry of the Mediterranean coast of Israel only. In this study, the influence of the near-shore bathymetry is investigated using multidimensional modeling for different near-shore bathymetries encountered around the globe. It is found that the above mentioned coastal effect is very sensitive to bathymetric changes. In general, the target response increases with increasing the bathymetric gradient. The latter also affects the optimum transmitter-receiver configuration and offset for obtaining the highest target response. Thus, the efficient application of the broadside Ex-Bz system requires a detailed knowledge of the near-shore bathymetry in the stage of a survey design.

## Geotechnical Site Investigations for the Gilboa Pump Storage Project – Analysis of Hydraulic In-Situ tests performed in deep boreholes

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The Gilboa Pump Storage Project (2 X 150MW) will supply 300MW of peak power to the IEC grid (Israel Electric Corporation) during up to 8 hours in a whole day. The reversible units will pump the volume of water backwards from the lower to the upper reservoir during up to 10 hours of the off-peak hours. The altitude of the Gilboa ridge rises to a height of 508m above sea level, and its summit is 628m above the town of Bet Shean, which lies 120m below sea level. The area is an agricultural area. The upper reservoir will be built on an agricultural plot of land and the lower reservoir near exiting water reservoirs. This will allow a 500 meters height difference for the high pressure shaft. The main underground structures in the project consists of 1,140m long main access tunnel, 960m long high pressure tunnel, 1,360m long low pressure tunnel, 500m deep high pressure vertical shaft, underground power house built of 2 large caverns with total volume of 45,000 m<sup>3</sup> and a series of temporary tunnels that will allow mobilization of materials during the construction. GGS (M. Levin Geological & Geotechnical Surveys Ltd.) was responsible for the geotechnical site investigation including performing deep core drilling up to depth of 570m and planning of the in-situ tests according to the specific technical specifications. The in-situ tests include single and double packer tests at various length and depths and with variable hydraulic pressures. These hydraulic tests were studied and analyzed for evaluation of the permeability of the rock mass, but can give additional information on the geo-mechanical behavior of the rock. Analyzing the test pattern and results can help in understanding of the deformation behavior of jointed rock mass.

## The geochemical history of the Dead Sea from dissolved chemical species and isotopes in pore waters

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During the winter of 2010-11 an ICDP-drilling project exposed a 456m long water-saturated core from the centre of the hypersaline Dead Sea (Israel). This research provides a unique perspective on the geochemical evolution of the lake from the analysis of dissolved chemical species and isotope proxies within the interstitial water gathered from samples collected at intervals along the core. Altogether 141 samples were taken and analysed over the length of the core, providing good resolution in results. Pore water analyses include major ion concentrations (Na<sup>+</sup>, K<sup>+</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup>, Sr<sup>2+</sup>, Cl<sup>-</sup>, Br<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>) and corresponding ratios (Na/Cl, Mg/Ca, Sr/Ca, Na/K), the carbon system (dissolved inorganic carbon (DIC) and  $\delta^{13}\text{C}(\text{DIC})$ ),  $\delta^{34}\text{S}(\text{SO}_4)$  and  $\delta^{18}\text{O}(\text{SO}_4)$ . The Ca-chloride nature of the Dead Sea brine (Ca/(HCO<sub>3</sub>+SO<sub>4</sub>)>1; Na/Cl<1) is maintained throughout the core, with Na/Cl and Mg/Ca ratios varying in the ranges of 0.19-0.73 and 1.88-9.56, respectively. The Mg/Ca ratio gradually increases from the bottom of the core (456 m) to depth of ~50m., suggesting that Mg<sup>2+</sup>, presumably derived from runoff water, accumulated in the water column, while Ca precipitated as aragonite, which is abundant throughout the core. The reversal in this trend from 50 meter upwards, which corresponds to the Holocene, may point to the impact of the saline thermal springs which currently discharges to the Dead Sea. The lowest Na/Cl ratio is found at a depth of ~250 meter, corresponding to a thick halite sequence. Between 207 and 90 meters the Na/Cl ratio rises. This depth range includes sediments from Lake Lisan (70-14 kyr B.P., depths of ~150-100m), the precursor of the Dead Sea which was significantly more diluted than the Dead Sea, suggesting that the rise is due to halite dissolution. These preliminary results show that flushing of the core during the drilling process was minimal and that the pore water may be used to study the evolution of the lakes in the Dead Sea valley and their brines.

## Rock fall hazard and risk assessment down the Gilboa fault slope: Hefziba and Biet-alfa (northern Israel)

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Rock fall is a natural hazard typical of cliffs and steep slopes. The trajectories of the falling rock-blocks down the slope are controlled by the geological and geometrical properties of the slope and the falling-rock surfaces. The frequency of rock fall events is generally controlled by the frequency of the triggering events such as extreme-weather and seismic activity. The kibbutzim Hefziba and Biet-alpha (hereafter the studied area), located at the foot of the Gilboa Mountains, are apparently in the range of falling rocks originated from the steep slopes above it. Two cases of rain induced falling rocks were documented the last 20 years. In this work we study the rock fall hazard in this area, focusing on the conditions for rock fall triggering, the expected rock-block size distribution and the down slope rock trajectories. This work will contribute to reduce casualties and damage induced by rock falls within the studied area and will enable planning of engineering protection measures. To accomplish the above we use the Colorado Rockfall Simulation Program (CRSP) and an in-house MatLab code, with a special emphasis on the calibration of the program to field conditions. We first mapped the origin of rock falls, measured size distribution of historical falling rocks, mapped the slope geology and geometry and measured roughness in-situ. We then derived the mechanical properties of the slope surface and the rocks using two independent calibration processes: back analysis of historical rock falls and a field experiment using high-speed photography. Calibration using historical falls showed that the initial velocity, which is related to triggering factor, had no effect on the maximal stopping point or energy but rather on rocks' stop point distribution along the slope. These results enable us to draw a map of the area under high hazard and a general assessment of the kinetic energy and the height of jumps along the blocks' track. Preliminary hazard evolution suggests that the volume of the common rock likely to fall and endanger the populated area is one cubic meter, where the maximal volume observed was 20 cubic meters; the rocks are only marginally stable and being held by a ledge of rock. We found that the southernmost part of the inhabitant area in Hefziba is under high rock fall hazard.

## Gas in shallow sediments of the continental shelf offshore Haifa Bay, Israel: physical characterization and controls

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High resolution seismic profiling along the continental shelf of Israel (at water depths <100 m) reveals an abundance of gas related acoustic reflectivity truncating the predominantly clay layered, presumably Holocene sedimentary cover. These corroborate variable patchy to semi-continuous bands of acoustic turbidity underlain by acoustic blanking. A series of surveys acquired by Charney School of Marine Sciences and Israel Oceanographic and Limnological Research offshore Haifa Bay, using our Georesources 1-2.5 kHz sparker system, map a zone of gas related reflectivity, a gas front, extending under a 7 by 12 km area of the middle to outer continental shelf (water depths of 30 to 100 m). The gas front is generally sub-parallel in our study area to the seafloor, with the free gas depth (FGD) varying mostly between ~10 to ~20 msec (~8 to 16 m) while the seafloor depths vary between 30 to 80 m. In many cases the gas front is clearly truncating the sedimentary layering as it preserves its own general trend, negating the possibility that the gas is sealed by any specific geological horizon. These observations suggest a primary bio-chemical reduction-oxidation control of Top Gas. Separating the acoustic turbidity to its specular and scattered components reveal that it represents a ~6 m stack highly reflective layers with randomly scattered diffraction between them. This observation suggests the concentration of gas presumably more porous layers, and transport of the gas in over-pressured bubbles fracturing up between these layers. We find that the second order variations of FGD strongly correlate with the morphology of Top Kurkar Unit, the sole of the presumably Holocene clayish sedimentary cover. We suggest that this correlation reflects an upward advection of the dissolved and gas phases of methane from the Kurkar Unit. The mechanical implications of our observations, indicating mechanical instability of the gas bearing sediments, must be taken into account in offshore development projects.

## Recognizing tsunami and seiche-triggered deformation of offshore sediments

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Most studies of tsunami and seiche related deposits have focussed on coastal and near coastal zones which are most readily accessible, with few investigations of deeper water settings and the potential soft-sediment deformation effects of such waves. The Late Pleistocene Lisan Formation outcropping to the west of the Dead Sea contains superb examples of sedimentary slump folds formed in water depths of <100 m. We have collected new structural data from an individual horizon that demonstrate that these gravity-driven slumps may be coaxially refolded and reworked by sheared folds and thrusts verging both back up and then down the palaeoslope. This suggests that it is possible to generate up-slope flow of material in some circumstances. A progressive increase in reworking and shearing is developed up through the folded sediment, culminating in a breccia layer that is capped by a thin, typically graded horizon of undeformed silt and sand. We suggest that these sequentially reworked deposits are consistent with seismically triggered tsunami and seiche waves that would flow back and forth across the main slump horizon triggered by the same earthquake. The overlying sands and silts that infill local topography are considered to be deposited from turbid suspension during cessation of wave action and represent homogenite deposits. Although tsunami and seiche waves have previously been both numerically modelled and directly witnessed in the Dead Sea Basin, this study forms the first detailed structural analysis and interpretation of potential reworking associated with such waves in offshore settings.

## Geodynamics of the Middle East domain since the Oligocene

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Several analog models were merged together to link between the post-Oligocene closure of the NeoTethys seaway, the northward migration of East Africa over a mantle plume, and the break-up of the Gulf of Aden and the Red Sea. The seaway closure since the early Neogene, which was derived from the northwards subduction of NeoTethyan lithosphere under south-central Eurasia, generated two styles of kinematic convergence. Its western branch presents the Tethyan subduction under south-central Eurasia along the Hellenic deformation front, generating the break-up of the Aegean Sea back-arc basin and the westwards migration of Anatolia. The eastern branch comprises the oblique convergence of Arabia with eastern Anatolia and Iran along the Bitlis –Zagros suture, which gradually shifted from subduction to collision. Since the velocity of the collision is slower than the subduction, the over-riding slab rotated, and developed extensional zones. Such extension triggered the resumption of the propagation of Carlsberg Ridge into the Gulf of Aden, after being stalled for nearly 30 Ma. It is presumed further that the break-up of the Red Sea in the Miocene was superimposed on the regional uplift and exhumation of the Arabo-Nubian Massif that was caused by a mantle plume in the Oligocene, a plume that subsequently affected the Ethiopian and the East African plateaus in the Neogene.

## Morphological features of Caesarea's Tsunami Sediment Deposits

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The discovery and study of physical evidence of past tsunami events is an important and relatively new field in Israeli tsunami studies. Sediment deposits offshore Caesarea have been interpreted as tsunamigenic, but to date, the overall morphological characteristics, lateral extent and continuity of these deposits were limited to the area in which trenches were dredged and cores collected. Thorough understanding of the deposit's distribution, and correlation between known positions has only been presumed by extrapolation, an often-inaccurate method. Comparing sub bottom geophysical profiles, collected specifically for this research, to previous excavations offshore Caesarea, can now enable us to differentiate tsunami horizons in the subsurface without extrapolation, in a much broader geographical scale, while distinguishing their unique sedimentological morphology. For example, two Mediterranean tsunami sediment horizons, dated to the 2nd and 6th-8th century CE, are recognizable in cores and excavations at depths of approximately 0.5 and 1.2 m below the seabed. In some cases the width of these beds is as thick as 80 cm, while in other locations the same deposit is less than 5 cm. While it is presumed these differences are related to variations along the sea bed, as well as to ancient features (for example, the harbor itself) within the tsunami wave's path, no work has been done to define this phenomenon. Better understanding of such differences is critical to coastal planning models and marine engineering designs. The study presented is two-fold; first, a dense seismic survey is conducted with a CHIRP remote sensing tool over previously excavated locations of tsunamigenic deposits. At the second stage, after all seismic profiles have been processed and interpreted; we will produce a detailed 3D map of the changing thickness of the deposits. The map of the tsunamigenic deposits will then be compared to the coastal features, archaeological and natural, so as to better interpret the deposition of these sediments, and ultimately construct the direction and impact of these tsunami events. Furthermore, Identifying and mapping tsunamigenic erosion contacts in the subsurface, will allow us to construct the pre-tsunami shallow bathymetry offshore Caesarea and learn the relative geomorphologic bathymetry change following these events. If successful, this research will better describe the Caesarean tsunamis from antiquity and allow more efficient identification of tsunami deposits worldwide.

## Chronostratigraphy of the Upper Cretaceous high productivity sequence of the Southern Tethys

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In this study we established a detailed and most updated chronostratigraphic framework for the high productivity sequence deposited in central and southern Israel based on eight different sections, covering a N-S transect of ~150 km. The Shefela basin (central Israel) is the largest and thickest of the oil shale basins in Israel and represents the broadest penetrated stratigraphic interval of the organic-rich section. We used the continuous core from the Aderet borehole drilled in the Shefela basin by IEI Ltd in order to construct a 'type-section' and detailed chronostratigraphic scheme for the high productivity (Si-P-C rich) sequence. The other sections studied represent a less extensive stratigraphic interval and were used for monitoring changes in the depositional system across the shelf. The N-S transect extends between the outer-shelf Shefela basin in central Israel (Aderet), Tel-Shoket (NS17), Biqat Beer-Sheva (NS23), Nevatim (M8), Mishor Rotem (PAMA outcrop and Bit68), Ein Mor (NS 20) and the inner-shelf Saraf/ZS28 core in the Zin basin. A total of twenty-four local correlatable datum levels were recognized using planktic foraminiferal biozones, benthic foraminiferal datums, lithostratigraphy and gamma-ray well log markers. The base of the Aderet core is dated as upper Santonian *Dicarinella asymetrica* Zone, older than 83.5 Ma, shortly under the Santonian-Campanian boundary. This age correlates with that of the upper part of the lower Menuha Fm. The upper part of the Chert Mbr (Mishash Fm) in the Negev is represented by the ~7 m 'Mishash Tongue' in the Shefela. Biostratigraphy has tied peaks in the P2O5 content and corresponding gamma-ray signals throughout the transect with those of the Phosphate Mbr in the Negev. The entire Oil Shale Mbr (OSM) of the Ghareb Fm in the Negev correlates with the TOC-rich zone of 100 m thickness, at the middle part of Aderet core, between 350-450 m depth with an average of 15.2 wt.% TOC. Moderate sedimentation rates recorded during the lower and mid-Campanian are considerably elevated at the base of the

*Pseudoguembelina palpebra* Zone (base of OSM in the Negev and TOC-rich zone in the Shefela), following a regional unconformity. In general, sedimentation rates decrease towards the southern sections yet are also apparently dependent on the depth and architecture of the different depositional basins. Moreover, the organic rich fraction within the pelagic sediments diminished at the upper part of the high productivity sequence in a step-like manner: first at the southern localities (PAMA, Negev), then further offshore (M8, Nevatim) and later still in the distal northern outer-shelf basins (Aderet, Shefela). The top of the Aderet core is dated as mid-Maastrichtian *Abathomphalus mayaroensis* Zone implying an age of ~68.3 Ma. This indicates that the full duration of oil shale accumulation in the Aderet core spans ~17 Ma.

## Paleoceanographic setting and depositional environment of a Late Cretaceous oil shale deposit in the Shefela basin, central Israel

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The Shefela basin is the largest and thickest (~350 m) of the oil shale basins in Israel, deposited within the Levantine high productivity regime and influenced by the extensive upwelling system operating in the Late Cretaceous along the Southern Tethyan margin. The organic-rich deposit accumulated between top Santonian (~86 Ma) and middle Maastrichtian (~68 Ma). A multidisciplinary approach was used for studying the oil shale succession of the Aderet core (IEI ltd) located in the central part of the Shefela basin. One of the interesting questions related to the preservation of large amounts of organic carbon is how variable were bottom water conditions especially in regard to oxygen levels on the sea floor. For that we used benthic foraminifera known to be sensitive recorders of bottom water conditions especially in intermediate to oxygen depleted environments. The changes in assemblage composition along the Aderet core, combined with life-mode characteristics of the common species was used for inferring bottom water oxygen levels and organic (food) flux to the sea floor at the time of deposition. A high number of 160 benthic foraminifera species were recognized along the 335 m of the Aderet core. The numerical abundance of benthic foraminifera changes considerably along the core. The highest values occur in the upper Menuha and Mishash formations equivalent horizons, from top Santonian to late Campanian with predominance of buliminids. Much lower values occur from approximately the base of the Pseudoguembelina palpebra Zone (~71.6 Ma) until the top of the core, when the buliminids were gradually replaced by the rotaliids. Three main benthic foraminifera assemblages were recognized using cluster and principal component analysis. These assemblages are distinguished by test morphology: (A) bi and triserial buliminids (*Praebulimina*, *Neobulimina*); (B) mainly uniserial nodosarids (i.e., *Siphonodosaria*); and (C) trochospiral rotaliids (divided into

two sub-assemblages; smooth containing “mini” pores (i.e. Gyrodinoides, Osangularia) and those containing larger pores (i.e. Gavelinellids, Cibicidoides). A major turnover is observed around the Campanian-Maastrichtian boundary (~70.6 Ma) when assemblage A, attesting to low bottom water oxygen levels, is replaced by assemblage C that indicates higher bottom water oxygen levels. This replacement coincides with the highest TOC value and a change in the general pattern of organic carbon accumulation along the Aderet core. Up to this point organic carbon concentration continuously increased since the top Santonian. From this point and onwards TOC concentration gradually decreased. One way to interpret these opposing trends using the benthic foraminifera ecological preferences, suggests that low oxygen levels prevailed during the ‘building-up’ increase in organic carbon content, and higher oxygen levels existed once TOC levels started to decrease. The bottom water oxygen levels as interpreted by benthic foraminifera match those deduced using factor analysis of trace elements and TOC content.

## Molecular evidence for Lessepsian invasion of soritids (larger symbiontbearing benthic foraminifera)

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The Mediterranean Sea is considered as one of the hotspots of marine bioinvasions, largely due to the influx of tropical species migrating through the Suez Canal, so-called Lessepsian migrants. Several cases of Lessepsian migration have been documented recently, however, little is known about the ecological characteristics of the migrating species and their aptitude to colonize the new areas. This study focused on Red Sea soritids, larger symbiont-bearing benthic foraminifera (LBF) that are indicative of tropical and subtropical environments and were recently reintroduced into the Israeli coast of the Eastern Mediterranean. We combined morphological and molecular phylogenetic analysis of soritids and their algal symbionts to compare populations from the Gulf of Elat and from a known hotspot in Shikmona. Our DNA sequence analyses show that all specimens found in Shikmona are genetically identical to one out of four soritid phylotypes living in the Gulf of Elat. Genetic analyses also show that the symbionts found in Mediterranean soritids belong to *Symbiodinium* clade F5, which is common in the Red Sea and also present in the Indian Ocean and the Caribbean Sea. Interestingly, the symbiont phylotype F2, endemic to the Red Sea has not been found in the Mediterranean. Our study therefore provides the first genetic and ecological evidence that the modern population of soritids found in the Eastern Mediterranean is indeed Lessepsian and that it occupies the same habitats in both regions.

## The Golan Volcanic Park

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Tens of exceptional geological-volcanological phenomena, which have been reported in the Golan, are not recognized in Israel, some of which are scarce worldwide. Still, for many years the phenomena were not known and not accessible to the public, thus many travelers passed by them without appreciating their uniqueness. Between 1990-1996 a few initiatives took place to establish the Golan Volcanic Park. None of these succeeded and the project was abandoned. In 2006 The Quarry Rehabilitation Fund (in the Ministry of Energy and Water Resources), along with the Golan Regional Council and the Ministry of Tourism, initiated the development of the first site. This was an abandoned quarry on the eastern slope of Mt. Avital, which turned into an exceptionally attractive geological-touristic site. It contains, among other exhibits, a 3D model of the area 700,000 and 100,000 years ago in comparison with its present morphology, and an audiovisual presentation of a volcano. Various volcanic phenomena are exhibited and explained in specially designed signposts. Recently accessibility has been developed to another attraction – the Great Volcanic Explosion Crater (Juba). Future activity includes the development of other 6-9 volcanic sites throughout the Central Golan.

## Paleoclimate variations during the Holocene as recorded in southeastern Mediterranean inner shelf sediments

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Sediments deposited on the south eastern continental shelf of the Levantine Basin are sensitive recorders of climatic and oceanographic variability affected by the north Atlantic and indirectly, through the variations in the Nile River discharge, by monsoonal climate systems. In order to reconstruct the influence of these systems on Holocene sediments two cores were taken off shore southern (V115) and central (V101) Israel coast at water depths of ~35 m, within the Nile littoral cell. The sediments were radiocarbon dated and analyzed for grain size, major and trace elements, and Sr isotopes. The cores, dated to 8,540 and 7,600 years BP respectively, show two distinct sedimentation regimes with high rates, of 190-140 cm/ka in the early Holocene, and significantly lower rates of 50-60 cm/ka during the last 5,500 years. Humid climate prevailed in the early Holocene and an aridification process started about 6,000 years ago and continues to these days. Two periods are also reflected by the  $^{87}\text{Sr}/^{86}\text{Sr}$  values: i) high values, ~0.71, in the early Holocene, reflecting a dominant signature of the White Nile and local streams and ii) much lower values, 0.7074~ in the southern core compared to 0.7080~ in the northern core, during the last 5,500 years, reflecting a strong fingerprint of the Blue Nile on the sediments adjacent to the Nile cone that rapidly disappear northwards. Additionally, the northern core shows ~1,500 years cycles that correlates with cold events known as the north Atlantic Bond cycles and with times of low monsoon activity in the Arabian Sea. Between those cycles, higher influence of the eastern Mediterranean climate system appears in the northern core despite the high activity of the monsoonal system, mainly because of its more distal location relative to the Nile Cone and its proximity to the Cyprus Low depression system.

## From ocean depths to mountain tops: uplift of the Troodos Massif (Cyprus) constrained by (U-Th)/He thermochronology and geomorphic analysis

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The Troodos massif of Cyprus rises to nearly 2000 meters above sea level and encompasses some of the world's best preserved outcrops of a fossil mid-oceanic ridge. Following its formation at a seafloor spreading center in Late Cretaceous times, this slice of the NeoTethyan oceanic lithosphere was uplifted and eventually exposed on mountain tops during the Neogene. The timing of final denudation was previously constrained to the Pleistocene by observations in the circum-Troodos sedimentary strata. However, quantitative thermochronological and geomorphological data from the Troodos Massif itself were not available. Here we use zircon and apatite (U-Th)/He thermochronology combined with geomorphic analysis to unveil the exhumation and uplift history of the Troodos Massif. Preliminary results show that zircon (U-Th)/He ages in the Troodos plutonic rocks are comparable with zircon U-Pb ages, dating the magmatic crystallization of these rocks to ca. 92 Ma. Due to its lower closure temperature, apatite (U-Th)/He dating is a more sensitive low-temperature thermochronologic tool, capable of quantifying the cooling history of rocks as they pass through the upper 1-3 km of the crust. In Troodos, reliable apatite (U-Th)/He ages vary between 20 and 5 Ma, indicating that the main phase of uplift and exhumation occurred during the Miocene. Geomorphic analysis of several erosion and uplift rate proxies across Cyprus delineate a bull's-eye zone with a radial drainage pattern at the center of the Troodos Massif, where local relief, channel steepness index and hillslope gradients are highest. The boundaries of this zone roughly correspond with the boundaries of exposed mantle rocks and suggest recent, focused differential uplift of this zone relative to its surroundings. The most likely mechanism, which could drive such a bull's-eye uplift pattern is hydration of ultramafic rocks (serpentinization) leading to a decrease in rock density and subsequent buoyancy of the lithosphere.

## Variations in salinity in the Wadi Ara, Ma'anit, and Karkur water supply wells

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The National Water Company, Mekorot, hired Ecolog Engineering Ltd to perform an environmental assessment for the Wadi Ara, Ma'anit, and Karkur wells. This assessment includes the analysis of hydrochemical (i.e., salinity) and physical (i.e., water level) data of 12 water supply wells for the last 25 years. The raw data was obtained from Mekorot database and evaluated against other studies associated with the Yarkon-Taninim aquifer. The findings suggest that the wells can be subdivided into 2 groups according to the salinity (concentration of Cl). The first group includes the Wadi Ara 1, 2, 3, Karkur 145 and Ma'anit 1, 2, 3, 4, 5 wells. It is characterized by low (up to 90 mg/L) and stable Cl concentrations that do not correlate with the fluctuations in water levels. The second group includes the Karkur 36, 38, 146 and Blume 2 wells that are characterized by higher Cl concentrations (90-120 mg/L) that correlate with the fluctuations in water levels. Blume 2 differs from the other wells in this group, in the way of showing some fluctuations in Cl concentrations. The hydrogeological settings and spatial distribution of the wells couldn't explain the division between the two groups. The confined conditions and technical specifications of the Karkur wells revoked the option of leakage from the overlying Mt. Scopus Group. A comparison to other water sources in the vicinity reveal that similar pattern of salinity variation were recorded in the Taninim springs, that are characterized by higher concentrations of Cl (up to 2300 mg/L) and receive a flow component of saline water from deep source/s. Based on the present study we believe that the second group of wells might be influenced by the same mechanism. The Blume 2 water well was drilled in 1948 by a private entity and later, handed over to Mekorot. Without detailed geological section it was difficult to determine what aquifer is utilized by the well. The proposed options include the Judea, Mt. Scopus, Avdat and Karkur Groups. It was found that the water level in Blume 2 match the water level of the Judea Group aquifer and the salinity shows the same trends. Fluctuations occur mainly during periods of low pumping rates and were accompanied with higher alpha radioactivity. Based on the above it is proposed that Blume 2 utilizes some water from the lowermost part of Mt. Scopus Gr., adjacent to the Judea Gr., while the majority of the water comes from the underlying Judea Gr. that is of higher permeability when compared to the Mt. Scopus Gr. During periods of low pumping rates, the relative input from the Mt. Scopus Gr. increases.

## The behavior of radium isotopes during the interaction of Dead Sea water with the aquifer rocks, an experimental study

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The Dead Sea water contains very high concentration of the long-lived radium isotope  $^{226}\text{Ra}$  (140 dpm/l). A recent study has shown that there is a large volume of Dead Sea water circulating in the aquifer and that the radium content of this water is reduced to 60 dpm/l soon after entering the aquifer, which affects the Dead Sea radium balance. A similar behavior was found for barium concentrations. Sources of radium in groundwater include recoil during thorium radioactive decay, desorption and dissolution, while the sinks encompass radioactive decay, co-precipitation and adsorption. We conducted experiments to study the processes that control the concentration of radium in circulated Dead Sea water and their kinetics, which included a batch experiment and a chromatography one. Two types of water were used: 1. Dead Sea water (DSW), which aimed at studying the removal of radium. 2. radium-free artificial Dead Sea water (ADSW), designed in order to quantify the desorbable fraction of radium on the sediments. In the Batch experiments, we used six sediment samples from the Wadi Arugot alluvial fan near the Dead Sea, which differed in their grain size and mineralogy. The experiments were conducted with DSW, and lasted for 1-2 months. In most experiments, radium and barium did not decrease or even significantly increased up to 270 dpm/l ( $^{226}\text{Ra}$ ) and 7.2 mg/L (Ba). However, two of the sediments showed a decrease in both elements. In the chromatography experiments we used one representative sand-size sediment. The experiments differed by their flow rate and water-sediment interaction time. In slow experiments (0.17 ml/min), there is a decline in DSW radium and barium concentrations after three days of interaction and steady state activities of 40-60 dpm/L ( $^{226}\text{Ra}$ ) and 1.5-2.5 mg/l (Ba) are achieved within 4-5 days. On the other hand, in fast experiment (7.2 ml/min) both elements were left intact. In ADSW batch experiments with the same sand-size sediment, radium and barium concentrations increased to 60-70 dpm/l (Ra) and to 1-2.2 mg/l (Ba), which is similar to the concentrations in circulated Dead Sea water. In an ADSW chromatography experiment, radium concentration first increased sharply to 126 dpm/l, and then decreased to 60 dpm/l within 7 days, though no steady state value is achieved. Barium increased and reached steady state value of 3 mg/l (2 days), which is comparable to DSW concentrations. Kiro et al. (2012) suggested that  $^{226}\text{Ra}$  and barium are removed from circulated Dead Sea water via co-precipitation with barite. The much faster decrease (days) observed in our

experiments is probably sediment-related, which should be further studied. The similarity between the results of the ADSW experiment and DSW concentrations suggest that concentrations in circulated DSW are buffered by the sediments.

## Sinkhole precursors along the Dead Sea, Israel, revealed by SAR interferometry

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The water level of the Dead Sea (Israel and Jordan) has been dropping at an increasing rate since the 1960s, exceeding a meter per year during the last decade. This level drop has triggered the formation of sinkholes and widespread land subsidence along the Dead Sea shoreline, resulting in severe economic loss and infrastructural damage. In this study, the spatio-temporal evolution of sinkhole-related subsidence and the effect of human activities and land perturbation on their development are examined through Interferometric Synthetic Aperture Radar (InSAR) measurements and field surveys conducted in Israel during 2012. Interferograms are generated using the COSMO-SkyMed satellite images and a high-resolution (0.5m/pixel) elevation model that is obtained from airborne Light Detection and Ranging (LiDAR). Thanks to this unique integration of high-resolution datasets, mm-scale subsidence may be resolved in both undisturbed and human-disturbed environments. A few months long precursory subsidence occurred in all three sinkhole sites reported in this study. The centers of the subsiding areas and successive sinkholes migrated, possibly due to progressive dissolution and widening of the underlying cavities. Certain human activities, such as filling of newly formed sinkholes with gravels or mud injections into nearby drill holes, seem to enhance land subsidence, widen existing sinkholes and even form new sinkholes. Apart from shedding light on the mechanical process, the results of this study may pave the way for the implementation of an operational sinkhole early warning system.

## From orthogonal to curved ridge-transform intersection: Trace element signatures in sheeted dykes and dunites of the Troodos ophiolite, Cyprus

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The dikes flanking the fossil spreading axis of the Solea graben in the Troodos ophiolite define two different geometries of ridge-transform intersection (RTI), suggesting two spreading phases. The earlier phase is expressed by N-S trending dikes that form orthogonal RTI with respect to the Arakapas fossil transform. The second phase is indicated by variable obliquely trending dikes defining a curved RTI. Dunite bands in the Troodos ultramafic section strike both orthogonal and oblique to the transform in accordance with the dike suites. Dunite bands within ultramafic sections of ophiolites were previously interpreted as channels of melt flowing towards the seafloor to generate the oceanic crust. They have been shown to form by an orthopyroxene-consuming MORB-peridotite reaction [1]. Our research examines chemical correlation between variably-directed suites of dykes and the similarly oriented dunite bands, in an attempt to bind the flow of MORB-like melt in the mantle and the middle crust, to the changing geometry of the RTI.

Proved as immobile during hydrothermal alteration, the Rare Earth Elements (REE) and High Field Strength Elements (HFSE) are chosen as means to distinguish the provenance of the crustal dolerite dikes relative to the dunite bands. To further avoid the effect of alteration on the whole rock composition, REE and HFSE contents will be measured in fresh magmatic clinopyroxene crystals by LA-ICP-MS. Preliminary petrographic and HR-SEM study shows that several dunite samples from Troodos include fine-grained interstitial clinopyroxene suggesting derivation from a coexisting melt. In others, however, orthopyroxene occurs, which could be explained only if these dunites were, in fact, olivine-rich cumulate layers. It is thus likely that more than one process was responsible for the formation of dunites in the Troodos ophiolite.

[1] Kelemen et al. (1995), *Nature* 375, 747-753

## Benthic Foraminiferal Response to the Removal of Aquaculture Fishcages in the Gulf of Aqaba-Eilat

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For about 20 years, finfish were reared in floating cages at the northern end of the Gulf of Aqaba (Eilat), Red Sea. The fish farms were removed from the sea in June 2008, creating a unique opportunity to monitor and assess changes in the benthos following the new conditions. This study summarizes three years of monitoring of the benthic foraminiferal assemblages, starting in July 2008, immediately following the removal of the cages until July 2011. The monitoring was done by monthly sediment sampling from stations at varying distances from the fish farm previous location, and sampling of the native seagrass *Halophila stipulacea* (Forsskal), that appeared in the area in summer 2009. The benthic ecosystem at the fish cages area was severely impacted by organic enrichment, resulting in an environment with no living foraminifera. Living foraminifera appeared in the sediments in early 2009, showing progressive increase in abundance thereafter. A clear difference in the rate of the rehabilitation process was observed on the spatial scale, related to distance from the point source of the organic enrichment. The living assemblages were dominated (86%) by *Assilina ammonoides* (Gronovius), a symbiont-bearing large foraminiferan normally found in the Red Sea at greater depths (>40 meter). Populations of *A. ammonoides* also revealed polymorphism in the coiling mode of their shells. Inflated involute and semi-involute forms dominated the living assemblages, whereas flattened evolute forms were most common in the dead assemblages from the period that preceded the fishcages. The re-establishment of the native seagrass community, *H. stipulacea* was an important factor enabling epiphytic foraminifera to colonize the previously impacted sediments. All living foraminifera species found on the seagrasses were also found in the dead assemblages, suggesting that seagrass meadows that existed before eutrophication were the main source of the species in the dead assemblages.

## Upgraded Algorithm for automatic site-effect evaluation from non-stationary seismic noise

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The overall goal of this work is to develop automatic tools for ambient noise horizontal-to-vertical (H/V) spectral ratio analysis to support site-effects evaluation. For solving the problem of instability of the H/V method in estimating site-effect from microtremor measurements, in this project we propose the interpretation of H/V ratio in terms of a transfer function of a linear dynamic system with input V and output H observed with non-stationary and correlated noise. A priori information about the model presented by a set of criteria is used for outlier removal via multi-time-window analysis. The method is realized via new automatic SEISPCTA program based on the SEISPECT MATLAB software previously used for the manual site-effect evaluation. With the help of the new program SEISPCTA in this work, we carried out H/V estimation for 5 sites in Israel. Maximal amplitudes and corresponding frequencies are estimated as H/V ratios in a sequence of time windows and then time windows are collected where the data are clustered around certain frequencies and amplitudes. The outliers in the new parameter space are automatically removed by using two automatic selection procedures: "Window Selection" (in time domain) and "Removing deviating H/V spectral ratio" (in frequency domain). The comparison of results obtained by automatic procedure and the expert analysis showed good agreement for the given 5 examples. All these results demonstrate the high value of the new program SEISPCTA for investigating site effects.

## Outcrop study of Carboniferous strata in SW Libya: unlocking reservoir potential and refining the onset of the Late Paleozoic glaciations

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Following discoveries of hydrocarbons in Carboniferous sandstones of SW Libya, this study has been conducted at the University of Manchester, UK and funded by the North Africa Research Group (NARG) industry consortium that consists of 12 energy companies. The study sought to: 1) describe, characterize and understand the controls on the deposition of the gas-rich reservoir facies; 2) provide additional elements in the mechanism that led to the onset of the Late Paleozoic glaciations. During three fieldwork seasons, a large outcrop dataset composed of sedimentary logs, rock samples, spectral gamma ray and outcrop observation was acquired in the SE of Libya. These data were complemented by subsurface data from exploration wells in the area. On the basis of these data, the Early Carboniferous reservoirs are interpreted to be: 1) thin and laterally extensive shoreface sandstones; 2) thick fluvial sandstones infilling incised valleys. The combination of high resolution correlation panels in different areas summarized in a high resolution regional sequence stratigraphic framework provides an understanding of the stratigraphic and geographic occurrence of these proven reservoirs in the studied area. At the same time, the paleogeographic location of observed strata situated at mid-latitudes, on the North Gondwana passive margin and on the interconnected Saharan platform (tectonically stable) leads to extend the Late Paleozoic glaciations to an older age (Visean) than previously thought. This study resulting of a University and industry collaboration has 1) considerably improved the description of the Carboniferous reservoir sandstones in SW Libya and; 2) bringing new timing for the onset of the Late Paleozoic glaciations.

## Mapping the extent of suspended sediments distribution in the Dead Sea after flooding events using satellite remote sensing methods

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Laminated sediments found in lacustrine environments are natural archives of palaeo-climate and palaeo-environmental records. They represent a high temporal resolution record, but at the same time pose the challenge of how to extract and interpret the buried information. As part of a broader research focused on the examination of laminated sequences deposited in the Dead Sea Basin (DSB) during the Late Quaternary, this work analyzed the possibility of using satellite images to estimate the extent of sediment dispersal during flash floods. Specifically, it is interesting to understand the extension and distribution of the suspended flood sediments from their initial outflow to the sea near-shore via their dispersion in the flood plume, and subsequent deposition at different locations offshore. Based on meteorological and hydrological data from the Dead Sea and its surroundings, several flash floods events were identified from the last 10 years. For those events, MODIS Sea Surface Temperature (SST) product was analyzed to confirm the existence of the flooding through the identification of the entrance of lower temperature fresh water into the Dead Sea. SST corresponds to a validated product generated from an algorithm that considers the thermal bands of the MODIS instrument on board both Aqua and Terra sun synchronous satellites. Considering that MODIS images are acquired in a coarse spatial resolution (1 Km), higher resolution satellite images (e.g. MERIS and Landsat) were later used to analyze the spatial effect of those flash flood events. MERIS images acquired between 2002 and 2012 over Israel as part of SISCAL services, were used for analysis. Based on these images, Total Suspended Matter (TSM) and Chlorophyll Concentration products were generated using specific algorithms for coastal and inner waters (Case II waters). Additionally, SST was produced from the subsequent Landsat image to the identified flash flood, providing spatial information of the sediment dispersal on a higher resolution (90 m). So far, it has been observed that MODIS SST product is an important tool for identifying and locating flash flood events. On the other hand, MERIS products have shown to be a good source for later spatial characterization of these events and of the suspended sediments they are carrying to the water body. These preliminary results lay the basis for making a long-term analysis about the overall contribution of the flash-floods to

the composition of the Dead Sea Basin, especially referring to its spatial extent. Moreover, these results are providing very useful information for planning the next field campaign of the project, in which TSM samples will be also collected among different depths within the flash flood plumes in order to calibrate the satellite images to be acquired.

## Simulating Performance of Earthquake Early Warning System for Israel

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In June 2012 the Israel Government announced the construction of the Earthquake Early Warning System (EEWS) in the country. During the first stage, the system would be designed to provide early warning for schools. The main characteristics of such a system are warning times  $T_w = T_s - T_{alarm}$ , i.e. time between the alarm signal and arrival time of the damaging S waves  $T_s$ , and the false alarms rate  $P_f$ , i.e. how often population (pupils) will be bothered by alarms not followed by serious shaking. The warning time depends on the mutual source-observer position (distance and the source depth), on the EEWS network configuration and on the EEWS algorithm. Network configuration (during the first stage) was chosen (according to international committee advise) as a staggered line of 50 stations along the regional main faults: the Dead Sea fault and the Carmel fault. For such a network, the S wave travel time  $T_s$  and the alarm time  $T_{alarm}$  were calculated using the standard 1D velocities model and certain assumptions regarding the EEWS algorithm and technical characteristics of the system (latencies due to packeting process and communication lines). The computation results are presented as maps (separate for each town- Jerusalem, Tel-Aviv, Haifa, Tveria), where color represents warning time for the town due to an epicenter. The false alarms, true alarms and missed alarm rates are computed for different EEWS algorithms and thresholds using the "real-time hazard assessment" approach (Iervolino et al., 2006), where epicenter and magnitude are randomly generated according to the given seismicity characteristics. Peak-ground acceleration PGA at a station is obtained according to the magnitude-distance prediction law.

## Neotectonics since Late Neogene: Evidence from the Subsurface of the Eastern Levant Basin (Shallow Seismics)

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Understanding the stress regime and mechanisms affecting the Mediterranean coast of the Levant is of considerable interest since the coast has repeatedly suffered destructive earthquakes and tsunamis through history. Interpretation of high resolution seismic surveys (2&3- D) acquired in the research area allow detailed mapping of middle Pleistocene stratigraphic units. The map shows young systems of faults that are suspected to be active today, as well as other unique structures. A disturbance lineament is identified offshore Nethanya, between the Gabriela and the Yitzchak structures located on the eastern ridge of the Syrian arc in the Levant basin. The NW-SE lineament (paralleling the Carmel fault) is a discontinuity of the seismic reflectors at different levels. Sub-Messinian faults north of the disturbance lineament show a significant shifting in the strike versus faults south of the disturbance lineament. The shifting is much smaller for faults within the middle Pleistocene. When overlaid on a seismicity map, the lineament separates between two domains of distinctly different densities of earthquake epicenters. Ongoing research is aimed at finding whether the disturbance lineament continues offshore and inland where it might cross densely populated urban regions.

## Towards Establishing a Coupled Nucleation and Crystal Growth Rate Law

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Crystal nucleation and growth are the main processes, which control the chemical precipitation of minerals. One of the main obstacles remaining for reaching a theoretical basis for the entire precipitation process is the absence of a theoretical coupling between both processes. While nucleation is defined by the formation of a new phase in the solution, crystal growth is mainly defined as the growth of existing nuclei, which is mainly a surface controlled mechanism. The unknown surface area of the growing nuclei limits the quantification of the growth process.

Most studies concentrate separately on nucleation and crystal growth processes. In order to link both processes, we conducted a series of batch experiments, in which gypsum nucleation was followed by crystal growth. In all experiments, the initial degree of saturation with respect to gypsum ( $\Omega_{\text{gyp}}$ ) was 1.8. Under these conditions, heterogeneous nucleation is the dominant nucleation mode. A wide range of batch reactors made of different material, and various stirring devices and speeds were used. The induction time of gypsum nucleation and the following rate of crystal growth were calculated for each experiment. The induction time (10-56 h) was found to be a function of the reactor material, while the rates of crystal growth, which varied over 3 orders of magnitude, were strongly affected by the stirring speed and its mode (i.e. shaking, magnetic stirrer, and magnetic impeller). The observed changes in  $\text{SO}_4^{2-}$  with time, due to combined nucleation and crystal growth, were fitted using a forward model that uses simple rate laws for nucleation and crystal growth of gypsum. The rate laws that were obtained are based on classical nucleation theory and heterogeneous crystal growth. Our coupled nucleation and crystal growth forward model assumes that the rates of heterogeneous nucleation depend on the properties and area of the reactors' surfaces but not on stirring. In contrast, crystal growth rates are strongly affected by stirring, presumably due to formation of new reactive surface area created by breaking up previously precipitated crystals.

## Submarine landscape along the eastern Mediterranean Israeli continental slope

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Numerous shallow submarine slope failures (scars and deposits) are observed in recent high resolution bathymetric grids of the continental slope off the Israeli eastern Mediterranean coast. The nature of these slope failures is currently not comprehensively understood as well as the question of whether the eastern Mediterranean continental slope is continuously or episodically unstable. We report here first steps towards understanding the present state of this submarine landslide system, which include mapping and analyzing the geology of the landslides and the hosting slopes. The continental slope extends from water depths of about 150 to more than 1000 m with a slope of less than 5 deg in general. Bathymetric grids with pixel resolution of 15 m till water depth of 700 m and 50 m till water depth of 1,700 m were used. Analyzing the bathymetry revealed three main submarine surface features: (a) numerous shallow landslides, within the upper sequence of the post-Messenian sediments. Landslide widths range between hundreds to thousand meters at the scar, with scar heights up to a hundred meters. The deposits of the landslides are not always mappable, but where they are, they lay up to a few kilometers down slope from the scar. Slope angles within the scars are 5 to more than 20 deg. At least two types of landslides were detected: Simple and apparently younger landslides, and complex and apparently older landslides. The older slides are composed of a primary scar cut by secondary scars and drainage systems. Landslides at the south of the mapping area are larger and occur at larger water depth. (b) a few kilometers long, north striking (slope parallel) step-like lineaments. Steps are facing the west and have height of up to 100 m and the slopes of up to more than 20 deg. The offset between parallel steps is less than a km to a few km. The steps are interpreted as surface expressions of growth faults rooted at the Messinian evaporates up to 1.5 km below surface; (c) a few channels were also detected, with steep walls of more than 15 deg, up to 2 km width and a few km length. They are concentric about the Dor disturbance. The nature of the channels is not clear yet. We observe relations between the main features: Landslides seem to either emerge from the over-steepened steps or be displaced by them. Hence, submarine landslides and steps are apparently contemporaneous. These relations also suggest that salt dynamics at depth is a main drive for at least some of these shallow slides. The above preliminary results testify to the complicated and highly dynamic nature of the studied continental slope, yet to be revealed.

## Pyrolysis of Type-IIS kerogen from the Shfela basin in Israel

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Within Israel is an oil shale resource estimated to have a potential of at least 250 billion barrels of producible oil, most of which is located in the Shfela Basin. Recent hydrology and appraisal studies of the oil shale in the basin suggest an attractive commercial target for in-situ thermal recovery. Slow-heating pyrolysis experiments of core samples obtained from the Ghareb member of the Shfela basin were carried out using a pressure-regulated semi-batch reactor to evaluate the oil and gas generation potential from an in-situ production process. The results indicate improved oil quality (API gravity, wt% sulfur, H/C ratio) relative to Fischer Assay samples due to thermal cracking and in-situ hydrogenation exhibited by performing the pyrolysis under slightly elevated pressures and slow heating rates. The effects of the sulfur content of this Type-IIS kerogen on the generation of oil and gas from the pyrolysis process is discussed as well.

## A model and a method to assess the transmission losses along an arid course stream: A case study of Nahal Paran

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Appropriate management of groundwater, runoff and water supplies in extreme arid regions is essential to the livelihood of these areas. Knowing the potential recharge of the aquifer is an important step in water resources management. The Paran course is the largest basin draining from the western side of the Arava valley, southern Israel. Floods and runoffs at the Paran result from rain initiating in the Sinai or Negev mountains and constitute a significant potential for water recharge resource to the Arava desert aquifers. We are suggesting a general simple model to calculate transmission losses along a stream course. We choose to describe the main pattern of the different phases of the recharge, using a common and simple model based on geometric progression decrease. In harmony to the hydrograph and groundwater level pattern, we assume that the transmission losses will show a similar behavior. Accordingly we established a model to describe the transmission losses of floodwater along a stream course. Respectively, the model calculates the transmission losses where data is being collected from two different hydrometric stations along the same course and when there are no tributaries contributing additional water to the volume measured at the upstream station. In order to calculate the transmission losses using the model, it is necessary first to calculate a common ratio, which can be define by the ratio of two sequential terms, of each specific flood event. According to the data collected in this research, the common ratio seems to be very similar for all flood events measured in the Paran course. This implies that the common ratio determined by a stream course is more significant than the flood characters. This conclusion is significant since it seems like it is possible to use the common ratio value as a stream course coefficient and then to assess transmission losses by this course coefficient using data collected in one station only. In addition, we discovered that the extinguishment of the wetted perimeter, from its maximum level until complete vanished, can be described by the same model. The outcome of these findings is that the model could possibly be used in the future as a new method for assessing water recharge, by measuring the maximum wetted active perimeter, and another wetted perimeter along the extinguishment phase of the flood. The effectiveness of this model is that it describes different phases of the water recharge process in a simple manner comprising the different variables that affect the process in one coefficient only.

## Vegetated linear dunes – chronologically discontinuous archives of several short-term and major dune growth episodes

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Quartz sand dunes cover massive areas defined as arid, making them a potentially important archive of past climates and environments. But, dunes, being highly dynamic and relatively uniform in sedimentological composition, often compromise this potential. Most inland dunes are of the linear type that have a sinuous planar shape. Linear dunes, also associated with active seif dunes, are elongated by oblique cross-(dune) crest deflection of sand grains due to acutely bimodal sand-transporting winds. This prevents formation of long-term and stratigraphically continuous internal dune structure (though fully exposed internal linear dune structures to support this conclusion are rarely found). Therefore, dating of the dune sand by luminescence methods is mainly restricted to the last (re)mobilization phase and cannot track earlier dune growth history. Vegetated linear dunes (VLDs), mainly found in low-latitudes, are characterized by a straight planar shape and a partial shrub cover, and have been proposed to comprise an independent dune type. The stratigraphic cross-section of the VLD includes a sequence of chronologically discontinuous sand units forming the dune core. The accumulation of the units is generally interpreted to pertain to major episodes of strong wind power when sand was available. Possible minor events of sand accumulation are presumed to have been erased by major episodes. The units, often structureless and of similar sedimentological properties can only be discerned by luminescence dating as contacts between units do not necessarily imply chronological boundaries. The VLD core is overlaid by a mantle of sand that while being intermittently morphologically and structurally configured by seasonal winds to depths of several meters, preserves the dune core stratigraphy. Therefore, in a sense, the VLD is a prominent sedimentary body archiving influential short-time and possibly extreme events. Based upon exposed dune stratigraphy, ground-penetrating radar profiling and morphologic analysis, coupled with spatial dense optically stimulated luminescence (OSL) dated full dune cores, the VLD core structure is found to repeat itself in the northwestern Negev (Israel) dunefield, for three time orders, each representing different palaeoclimatic and palaeoenvironmental conditions. Accordingly, a full dune core coring strategy for retrieving luminescence ages which date the major VLD core units is required for adequately dating a vegetated linear dunefield. Exposed sections of VLD cores that reveal the full dune core structure are very important

for such dating strategies. The VLD type is suggested to inherently comprise a distinct archive of unique past conditions, mainly since the last glacial. However, further study is required for robust palaeoclimatic interpretation of these archives.

## Rapid Anthropogenic Response to Short-Term Local Aeolian and Fluvial Palaeoenvironmental Changes during the Late Pleistocene-Holocene Transition (at the Edge of the Northwestern Negev Dunefield, Israel)

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Several prehistoric camp sites, mainly attributed to the Natufian culture, were excavated over the past decades along Nahal Sekher on the eastern edge of Israel's northwestern Negev Desert dunefield. In this research we reconstruct the aeolian and fluvial environs of these sites by integrating field mapping, stratigraphic sections, particle-size analysis, sand spectroscopy, optically stimulated luminescence ages, and radiocarbon dates. Intermittent surface stabilization and aeolian deflation are hypothesized to explain the appearance of the Natufians who probably inhabited the region during the last main Negev dune encroachment in a windy palaeoenvironment. It is argued that the residual sequences of diagnostic low-energy fluvial fine-grained deposits (LFFDs) documented around the Natufian sites resemble the ephemeral event-layers of hyper-concentrated flow into the ever-emptying dryland-type reservoirs formed by dunes that dammed wadis. The location of the Natufian sites along the shorelines of these water bodies point to rapid but temporary anthropogenic responses to short-term and improved local palaeoenvironmental conditions during the Late Pleistocene-Holocene transition.

## Late Holocene dune mobilizations in the northwestern Negev dunefield, Israel: A response to combined anthropogenic activity and short-term intensified windiness

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The study of the effects of past climates on ancient cultures is usually based on geologic records pertaining to rainfall and temperature fluctuations and shifts. This study proposes a paradigm of anthropogenic activity and windiness fluctuations to explain aeolian sedimentation and dune mobilization in the northwestern (NW) Negev Desert dunefield (Israel). The proposed paradigm contributes a different approach to estimating the effect of climate changes on the unprecedented agricultural and urban settlement expansion during the late Roman to Early Islamic period in the northern and central Negev Desert. This study builds upon the late Holocene cluster of luminescence ages of Roskin et al. (Age, origin and climatic controls on vegetated linear dunes in the northwestern Negev Desert (Israel), *Quaternary Science Reviews* 30 (2011), 1649-1674) coupled with analysis of archaeological finds and historical texts. We suggest that whereas the NW Negev dunefield was generally stable during the Holocene, intermittent dune mobilization during the late Holocene, at ~1.8 ka and mostly 1.4–1.1 ka (~600–900 CE), are linked to periods of human occupation. The idea that the last glacial dune encroachments alone that formed the NW Negev dunefield is connected to cold-event windy climates that may have intensified East Mediterranean cyclonic winter storms, cannot explain the late Holocene dune mobilizations. We conceptually model a connection between late Holocene dune mobilization, widespread anthropogenic occupation and activity, and windiness. We maintain that historic grazing and uprooting shrubs for fuel in the past by nomads and sedentary populations led to decimation of dune stabilizers, biogenic soil crusts and vegetation, causing dune erodibility and low-grade activity. Short-term events of amplified wind power in conjunction with periods of augmented anthropogenic activity that triggered major events of dune mobilization (elongation) and accretion have been preserved in the dune chronostratigraphy. Because they were short lived, the dune mobilization events, corresponding windiness, and probable dustiness, which were examined affected the northern Negev landscape differentially. However, they cannot be proved to have affected the environment sufficiently to influence the decline of the late Byzantine and Early Islam agricultural establishment. This study demonstrates the sensitivity of dunes in arid and semi-arid regions to a combination of local and short-term

fluctuations in windiness at times of widespread grazing (anthropogenic activity). The results remind us that in similar future scenarios, sand mobilization may be similarly retriggered to varying degrees.

## Lithostratigraphy and strontium isotope composition of Neogene formations and water bodies in the Lower Galilee and Central Jordan Valley

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The lithology and  $87\text{Sr}/86\text{Sr}$  ratios were determined in three stratigraphic sections: Kokhav Hayarden (KHY), Hurvat Zeev (HZ), and Nahal Hamud (NH) of the late Miocene Bira Fm. and the early Pliocene Geshel Fm. in the Lower Galilee and the Jordan Valley. Both formations are dominated by carbonate units with variable amounts of dolomite, calcite and clays. Evidence for ongoing volcanic activity was found throughout the sequence studied, characterized by interbedded volcanic flows and pyroclastic material. It appears that most of sediments comprising the Bira Fm. and all sediments comprising the Geshel Fm. were deposited in continental-lacustrine environments, except three marine incursions in the Bira Fm., that are manifested by marine to brackish macrofauna assemblages.  $87\text{Sr}/86\text{Sr}$  ratios in the carbonates of the Bira Fm. (KHY, HZ, and NH sections) lie in the range: 0.70525 - 0.70795, while the Geshel Fm. carbonates (HZ and NH sections) have higher  $87\text{Sr}/86\text{Sr}$  ratios ranging from 0.70729 to 0.70869. Combined with calculated  $\text{Sr}/\text{Ca}_{\text{water}}(\text{eq.})$  ratios, the  $87\text{Sr}/86\text{Sr}$  ratios indicate three water types: basaltic water, regional runoff, and a brine component (defined by the evaporite samples of Raab et al. (1997)). The carbonates of the Bira Fm. from the HZ and NH sections lie along the mixing lines between runoff and basaltic water and show a trend towards the brine component. Dolomitic rocks of the Bira Fm. from the KHY section show a trend towards the basaltic waters. The Geshel carbonates were deposited from freshwater bodies dominated by regional runoff. We found no evidence for a "pure" Neogene seawater component and possibly all marine incursions underwent water-rock interaction with the regional aquifers (basalts and carbonates) and their  $87\text{Sr}/86\text{Sr}$  ratios were modified. A similar process was suggested for the Sedom lagoon (Stein et al, 2000).

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Stein, M., Starinsky, A., Agnon, A., Katz, A., Raab, M., Spiro, B., Zak, I., 2000. The impact of brine-rock interactions during marine evaporite formation on the isotopic Sr record in the oceans: Evidence from Mt. Sedom, Israel. *Geochimica et Cosmochimica Acta*, 64(12):2039-2053.

## 'Active' and 'Potentially Active' Faults that Rupture the Surface in Israel, Updates 2013

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We present an update of the map of active faults in Israel. The map is based on geological maps at the scale of 1:50,000 rather than 1:200,000, thus enabling better compliance with the requirement that faults be 'well-defined' as well as facilitating assessment of age faulting. As in the previous 2009 map, 'active' and 'potentially active' faults are marked on the same map. An 'active fault' for the Israel Standard 413 "design provisions for earthquake resistance of structures" is one that exhibits geological evidence for having ruptured the earth surface at least once in the last 13,000 years, therefore, constituting a potential hazard to structures that might be located across it. A 'Potentially active fault', as defined herein for the present update, is either a fault that is a direct branch of an 'active fault' or a fault that has ruptured the surface at least once within the time range of 13,000 and 35,000 years. In addition to marking the faults, the 2012 map demarcates adjacent areas along them, which are considered 'active fault zones', in accordance with the Israel Standard 413 requirements.

## Jonah Ridge

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The Jonah ridge, located 80 km west of the Israeli coastline in the deep Levant Basin is buried under more than 3 km of Late Tertiary sediments. It is associated with one of the largest magnetic anomalies in the Levant Basin, though, interestingly, an equivalent gravity anomaly is not detected (Rybakov et al., 1994; Rybakov et al., 1997). This structure is quite enigmatic; several hypotheses for the structure origin were suggested such as a compressional Syrian Arc structure (Folkman and Ben-Gai, IGS abstract, 2004; Gardosh et al., 2008), or a giant volcanic edifice (Rybakov et al., 2011). We performed a detailed imaging in depth in order to better represent the structure boundaries, distinguish thickness changes toward the structure and perceiving internal reflectors. The Pre-Stack Depth Migration method is a key for improving the accuracy of the imaging by resolving detailed velocity variation, associated with both structural and stratigraphic targets. We present the results of 2D seismic Pre-stack Depth Migration that crosscut Jonah ridge. After obtaining the initial interval velocity using the Coherency Inversion method, the procedure includes several iterations of tomography calculations followed by a depth migration. The procedure is performed in a layer-stripping method from the upper part of the section downwards. Results of Pre-stack Depth Migration are a depth section and its interval velocity model. The newly produced depth migrated section reveals an on-lap pattern over the Jonah structure displayed by relatively flat reflectors that are approaching the ridge and progressively cover it. These reflectors seem to be tilted only very close to the ridge. This pattern is different from the gradual thinning of internal layers towards classical Syrian Arc type structures. The results of the interval velocity analysis reveal high velocities inside the Jonah ridge which is in contrast to its surrounding.

## The Differences in the Extent of Aquifer Salinization Next to an Estuarine River

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Surface water-groundwater interaction occurs both along the coastline and along estuarine rivers. While seawater intrusion was widely investigated, seawater intrusion via estuarine rivers was hardly studied. The riverbed of the Alexander River is partly below sea level, therefore it is subjected to seawater encroachment, which reaches 4-5 km upstream. The river mouth is usually blocked by a sandbar, which means that major sea encroachments occur mostly during or shortly after flood events (2-3 times a year), when high discharge flows and high sea conditions combine to breach the bar. In such events, bottom water salinity of 27 (PSU scale) may be observed at a distance of 4 km upstream. Shortly after the flood (>week), the sandbar is re-built, and salinity of the bottom layer starts decreasing. Nevertheless, dry season salinity remain relatively high, although bottom layer salinity usually does not exceed 15 and 7 (500 and 3,900 m from the coastline, respectively). In an earlier study, we found that aquifer salinization is quite limited but variable along the river. At 1,800 m from the sea, aquifer salinization was observed up to 100 m from the river, with salinities up to 10-12 observed in boreholes 45 m from the river. On the other hand, at 300 m from the sea, salinities varied significantly, between 10 to 36, but were limited to a few meters from the river. Recently, additional six boreholes were drilled into a sandy dune, along a transect perpendicular to the river 300 m from the sea, on the southern bank of the river. Salinization is observed up to at least 85 m from the river. Unlike the above two sites, Salinity profiles in boreholes suggest that there is a clear permanent interface in this area with average salinity of 1 and 6, above and below the interface, respectively. A continuous salinity measurement in boreholes (300 m from shoreline) in northern silty bank shows intense salinity reaction to changes in the river, whereas salinity changes in the southern sandy bank of the river were negligible. The low tritium content of several groundwater samples imply that the water age is at least 50 years old, suggesting that they are remnants of old saline water body. At all the locations, salinization is limited to the superficial aquifer, and the regional aquifer (depth>15 m) is left intact. The variability in salt content and in the extent of aquifer salinization is probably related to heterogeneity in the near-river conductivities due to sediment variability. In other studies (e.g. in Australia), salinization was observed to much larger distances from the river (e.g. 500 m), probably due to different hydrogeological.

## Seismic Hazard - The Structural Engineer Point of View

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A seismic hazard evaluation is mainly done for the use of the structural engineer. He is the one to apply the seismic hazard conclusions into the structural design of the building. The most detailed and comprehensive seismic hazard survey, concluding by indicating "high hazard" or "low hazard" will be of no use for the structural engineer as they cannot be applied in the basic design formulas of the seismic design codes. A seismic hazard survey must be concluded with clear quantitative - numeral parameters - design acceleration and displacements. These parameters are the ones to be applied by the structural engineer, that means that the conclusions of the seismic hazard survey actually overlaps the earthquake loading design parameters that are used by the structural engineer. Specifically, the basic parameter to be provided by the seismic hazard survey, is the design response spectra, including site amplification and topographic or basin effects. Other parameters are settlements due to soil liquefaction and horizontal displacements as a result of lateral spreading. Surface fault rupture is a very dangerous phenomena for buildings, this parameter may evaluate as a probabilistic parameter similar to the evaluation of probabilistic peak ground acceleration.

## Mines Reclamation in Rotem Amfert Negev

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The Israeli phosphate industry began in the Oron site in 1952 as a governmental company. Zin and Rotem sites began operations in the seventies. Until the eighties the awareness for reclamation was rather low and there were no demands to do it. The first reclamations actions were topographic ordering, and the most famous ordering was a huge environmental sculpture lately known as "the banana", in the field of "Yorke'am North" in the Zin mine. This was done almost without considering landscape development and ecosystem restoration. Over the years and in cooperation with the Nature and Parks Authority, reclamation processes were greatly improved. Today the process is actually integrated as a part of the mining plan and activity. The reclamation needs are taken into account in the mine planning and design stage. This method allows to keep only small disturbed cell and to restore it during the mining progress. For design and reclamation we work with an architect and with the counseling of an ecologist. The rehabilitation method now enables the renewal of the desert ecological system, beginning with the development of soil crusts and seasonal plant appearance. At the end, a few perennial plants start to grow. Rotem established a special department to handle the reclamation works. This work is done in full cooperation with the Nature and Parks Authority. The goal of this activity is to achieve a good ecological rehabilitation of the mined area. The rehabilitation stages are: 1. Removing top soil. 2. Refilling of mined pits. 3. Maintaining the height of the original surface. 4. Surface treatment by tractors and reducing slopes. 5. Connecting drainage channels with the major wadis. 6. Top soil scattering. 7. Blurring the surface.

## Illitization at shallow burial conditions of Pliocene calcareous shales of the Sedom Formation

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Illitization of smectite is an important reaction in deep burial diagenesis, yet the formation of illitic clays in sedimentary conditions under near-surface temperatures has also been suggested. The present study demonstrates an illitization process that took place at shallow burial conditions in Pliocene calcareous shales of the local Sedom Formation (Fm.) in the potassium-enriched environment of the Dead Sea basin. The Pliocene Sedom Fm. is divided into five members (Mb.), composed of halitic rock salts or calcareous shales. This formation is exposed in Mount Sedom, which is a salt dome (salt diapir) located in the Sedom area of the Dead Sea Valley. The deposition of the rocks of the Sedom Fm. took place during the Pliocene in the Sedom Lagoon, which was a marine tongue of the Mediterranean Sea into the tectonic depression of the Dead Sea Rift. The rock salts were deposited in an evaporative hypersaline sabkha environment of the Lagoon. The changes in deposition of the rock salt units with the calcareous shale units demonstrate changes in the conditions between a hypersaline evaporative environment and a saline environment with a high influx of detritus. In the present study, the calcareous shales of Hof and Benot Lot Mbs. of the Sedom Fm. were analyzed using XRD, FT-IR, SEM, EDS and thermal analyses. Both members have never been buried under more than 1 Km of sediments. Results from these analyses show that the principal clay minerals of the calcareous shales of the Hof and Benot Lot Shale Mbs. are illitic illite-smectite of  $R>3$  type, discrete illite (DI) and some kaolinite. Chlorite is commonly found and palygorskite is occasionally observed. The main carbonate mineral is dolomite. The sources of the calcareous shales were detrital sediments deposited in the saline Sedom Lagoon from surrounding Cretaceous rocks. The major detrital minerals in the initial sediments were smectitic illite-smectite of  $R=0$  type, kaolinite, calcite and quartz. This composition is similar to the composition of recent alluvium in the area, which may imply that the same depositional environment existed during the time of the Sedom Lagoon. The results reveal that the precursor smectitic clay of the detrital sediments was transformed to illitic clays due to illitization at shallow burial conditions. The illitization took place due to the reaction of the smectite clay with interstitial potassium-enriched brine, derived from the saline Sedom Lagoon. This process occurred due to penetration of the brine into the detrital sediments and the contact of the smectitic clay with the soluble potassium of the brine, in association with dolomitization as observed by the presence of dolomite

as the main carbonate mineral. The dolomitization took place due to elevated magnesium to calcium ratios that characterize the interstitial brine derived from the saline Lagoon.

## Recording the Early Mesozoic drift of the Levant region across the equator by climate-sensitive rocks and clay minerals of the Makhtesh Ramon sequence

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The Early Mesozoic was a time of the breakup of Pangaea and the drift of Northern Gondwana from the southern to the northern hemisphere. At that time, the Negev region was located in the Levant between the northwest Arabian part of the Gondwana and the southeastern margin of the Neo-Tethys Ocean. Therefore, the Triassic-Jurassic sedimentary sequence of the Negev contains a record of the drift of the Levant region from the southern hemisphere through the equator to the northern hemisphere. In the present study the record of the paleoclimate changes by the crossing of the climate belts at that time is interpreted from the Late Triassic to Middle Jurassic sequence exposed in Makhtesh Ramon. The interpretation is based on climate-sensitive rocks and clay minerals of the Early Mesozoic rock-units. Samples of rocks and clay minerals were analyzed using XRD, FT-IR, SEM, EDS and thermal analysis. The Triassic drift in the southern hemisphere is recorded in Makhtesh Ramon by the Middle Carnbrian Mohila Formation (Fm.). The evaporative rocks, anhydrite, gypsums and dolomites of this formation represent deposition in a hypersaline lagoon-sabkha environment. This denotes an extremely dry, warm and arid climate under a desert belt. The transition in deposition to evaporites with algal bituminous limestones in this formation implies a reduced salinity of the lagoon. Their deposition in coastal marshes represents a higher influx of meteoric water under a higher humid climate, probably the semiarid climate of a subtropical belt. The regional erosion during the Norian, the development of an extensive karstic relief and surface unconformity require the removal of material by leaching with heavy rains under a semihumid to humid climate closer to a tropical belt. A unique Jurassic record of tropical humid climate with high precipitation and accelerated leaching of parent rocks is detected by the developed of residual soils, laterite and flint clay (bauxite) of the Hettangian-Lower Sinemurian Mishhor Formation. This record probably represents the passing of the Negev area through the tropical belt and thus the drift of the Levant region through the equator at that time. The initial drift in the southern hemisphere is recorded by the transition in deposition of the residual soils of the Upper Sinemurian-Lower Pliensbachian (Carixian) Ardon Formation. These soils with ferruginous kaolinitic claystones, paleosols and subordinate calcic horizons represent a reduced leaching of parent rocks and a return to weathering under a semihumid climate. A more drastic return to a semiarid climate in the

subtropical belt is observed by the accumulation of non-leached terrestrial quartz sandstone of the Toarcian, Aalenian to Lower Bajocian Inmar Formation.

## A study of the mass-gain of ancient pottery in relation to archeological age using thermal analysis

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The study of the mass-gain of ancient pottery in relation to the archeological age is of interest in view of pottery dating. The mass-gain takes place by slow processes of rehydration and rehydroxylation in the fired-clay ceramic. In the present study, actual mass-gain values of pottery of different archeological ages (up to 6,500 years old) are obtained by using a thermal analysis method. The mass-gain is measured from the mass-loss of the turn-over processes of dehydration and dehydroxylation occurring during the heating of pottery in a thermal analysis apparatus. The results were normalized here without the amounts of calcite in the ceramics, which is calculated from the mass-loss of the processes of decarbonation. Regression curves of the mass-loss values as a result of dehydration, dehydroxylation and a combination of the two processes, versus the age of the pottery show that mass-loss values generally increases together with the archeological age of the pottery. Well correlation coefficient ( $R^2$ ) values are observed for regression curves of the average mass-loss values, which were calculated for the distinct archeological periods. Deviations observed in the mass-loss values of individual pottery in relation to the ages are related to variations in ceramic composition, level of firing and burial conditions of the pottery over time. For accurate dating of individual pottery samples, the type of fired clay, amount of calcite, amount of coarse particles (temper) in the pottery and the level of firing should be taken into account.

## Nanograins Form Carbonate Fault Mirrors - Observations from the Field and from Experiments

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Many faults are naturally polished, characterized by extreme smooth, glossy and hard surfaces termed fault mirrors (FMs). Fault mirrors are slip surfaces that appear in a variety of tectonic environments and rock types. These surfaces are a form of slickensides that is characterized by high visible-light reflectivity. Recent experiments find that FMs form during rapid sliding between rock surfaces. The structure of FMs and the mechanism of their formation are important for understanding the mechanics of frictional sliding in general, and during earthquakes in particular. Here we characterize the small-scale structure of natural carbonate FMs from 3 different faults along a tectonically active region of the Dead Sea Transform. Atomic force microscopy measurements indicate that the FMs possess extremely smooth surface topography, accounting for their mirror-like appearance. Electron microscope characterization tools revealed a thin ( $< 1 \mu\text{m}$ ) layer, composed of tightly packed nano-scaled grains, coating a rougher layer composed of micron-size calcite crystals. The crystals contain closely-spaced, plastically-formed, mechanical twins, which define new sub-grain boundaries. The narrow sub-grains are observed to buckle and break into sub-micron pieces near the sheared surface. This observation suggests a new brittle-ductile mechanism for nano-grain (NG) formation. In addition, observations of rounded NGs and lack of scratches on the submicron scale, suggest that ductility may control deformation within the NG layer itself. The role of ductility during frictional sliding, both in forming the NG layer, and in the deformation process of the powder, may be critical for understanding shear on geological faults. To augment these field observations, tens of experiments were performed in a rapid rotary shear machine, aiming to clarify the formation mechanisms and the physical behavior of FMs. The experiments were ran on three different types of limestone samples, among them one from Kfar Giladi quarry, from which one of the natural above-mentioned FMs was taken. Experiments shear two samples one against the other, under low normal stresses of  $\sim 1 \text{ MPa}$ , at different slip velocities. Results suggest that mirror-like surfaces form only at high slip rates (above  $\sim 5 \text{ cm/s}$ ). The experimentally obtained FMs are very similar to those observed at the field in both their appearance to the naked eye and in magnification into the nano-scale. The formation of FMs was also observed in these experiments

to coincide with frictional weakening. The coupling between FM formation and the weakening process is not well understood, yet valuable clues are provided by the main FMs components: the thin layer of nanograins (powder) and the smooth hard surface they form.

## 1,000 years of Global climate changes, revealed from the reef builder vermetid *Dendropoma petraeum* oxygen and carbon isotopic records

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Reconstruction of the last millennium climate provides a framework to assess the anthropogenic climate change in the context of past climate variability. Here we present a continuous reconstruction of Sea Surface Temperature (SST) and the stable carbon isotopes of the Dissolved Inorganic Carbon ( $\delta^{13}\text{CDIC}$ ), produced from the South-Eastern Mediterranean (SEM) reef forming vermetid *Dendropoma petraeum* oxygen and carbon stable isotopes at multi-annual resolution. Spanning over the past millennia, this reconstruction reveals a relatively moderate fluctuations, with an amplitude of about  $1^\circ\text{C}$ , during the period 975-1600 AD. Relatively warm and variable SSTs are found during the period 975-1250AD, within the end of the Medieval Warm Period. A period of cold SST's appears from about 1450-1650AD, within the peak of the Little Ice Age. It is followed by a 400-yr long-term warming trend, during which the 20th century was the warmest on record. Our SST reconstruction shows high correlation to 250-yr Mediterranean instrumental air temperature and exhibits a pattern similar to the North Hemisphere (NH) temperature reconstruction. Thus, the vermetid derived SST record mainly reflects changes in air temperatures of the NH, amplified for this specific region. A high correlation with the increase of monsoon winds over the Arabian Sea reflects a possible pan-tropical forcing over the SEM long-term warming. The  $\delta^{13}\text{CDIC}$  reconstruction reveals a series of centennial scale fluctuations, over the period 975-1750AD, which diminished during the mid 18th century. It is followed by a distinct  $\delta^{13}\text{CDIC}$  depletion trend that closely follows the lowering trend of atmospheric  $\delta^{13}\text{CCO}_2$  (the Suess effect). The  $\delta^{13}\text{CDIC}$  cycles over the period 975-1750AD are considered as fluctuations in primary production. Their pre-industrial diminished, is correlated with the SEM warming trend, and therefore suggests a possible pan-tropical forcing. Hence, the recent warming and decreased productivity, since about 1750AD, reflects a new state of the SEM, over the anthropogenic era that exceeds the last millennium variability.

## The effect of fluid flow on stick-slip behavior in models of saturated fault gouge

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Shear in natural faults often occurs within a gouge layer, an unconsolidated, fluid-saturated collection of fine-grained material. Because of the dilation and compaction associated with shearing granular material, the interactions between grain motion and fluid pressure may exert an important control on fault-stability. To explore this dynamic system, we use a grain-scale model based on the discrete element method, coupled with a continuum model of fluid pressure that assumes a Darcy-like flow (Goren et al., JGR, 2011). We conducted a series of numerical experiments to explore the sliding stability of a gouge layer. The layer consisted of circular two-dimensional grains trapped between parallel rough boundaries (rigid walls), representing the fault gouge and the surrounding fault blocks, respectively. The system was taken to be periodic in the layer-parallel direction. We fixed one wall and imposed a fixed normal stress on the other wall, creating a confining pressure in the layer. A variable shear stress was applied to the movable wall, proportional to the difference between the current wall position and a loading point moving with a fixed velocity. This model can produce wall motion ranging from continuous or oscillatory creep near the driving velocity (stable sliding) to stick-slip behavior (unstable sliding). We quantified the stability of the sliding, and show that it is controlled by a single dimensionless parameter, as predicted by a simple block-slider theoretical model. Stick-slip behavior in dry granular systems (no fluid pressure) is promoted by large confining stresses and small driving velocities. We run the same set of experiments with fluid and permeable (drained) boundaries. In these cases dilation and compaction must be accompanied by fluid flow into and out of the layer. Under some conditions, the saturated systems are slightly less stable than the identical dry system. Stability is controlled by the same parameter, but with applied normal stress replaced by the peak effective normal stress. When permeability within the gouge layer is small (10-16 m<sup>2</sup>), the time scale of a slip event is small compared the time to equilibrate pressure with the surrounding rock. Therefore, even if the gouge layer is well-drained by a permeable rock, the region of the slip localization acts undrained. This lowers local fluid pressure and increases the effective normal stress. Therefore, we find it is the peaks in effective stress (not the time-averaged value) that control the sliding stability. Some slip events are preceded by extended

dilational creeping periods, indicating that dilational hardening initially inhibits some slip events, eventually triggering a larger slip nearby in the layer.

## Metabolic dissolution of $\text{CaCO}_3$ in the sediments of a deep tropical marginal sea: the Gulf of Aqaba case study

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Marginal seas are the first marine regions to experience anthropogenic influences due to their relatively fast water overturning times and their proximity to pollution sources. Nevertheless, tropical marginal seas are not usually considered to be important sites for  $\text{CO}_2$  sequestration due to rapid organic matter re-mineralization rates and high super-saturation with respect to calcite and aragonite. The northern Gulf of Aqaba is characterized by deep water overturning at least twice a decade that equilibrates the entire water column with the atmospheric  $\text{pCO}_2$ . The last deep mixing event at 2012 reached depths of at least 830 m. This oligotrophic sea is also prone to pollution from the rapid urban development. Untreated effluents were spilled to the sea until 1995, followed by a high nutrient load from fish farms between the years 1996 to 2008 that doubled the productivity at the early 2000's (David Iluz, unpublished). We extracted and analyzed interstitial waters from cores taken in the deep shelf sediments of the northern Gulf of Aqaba (at water depth of 500-700m). High vertical resolution analyses of the top three centimeters of the sediments were performed using oxygen and pH microelectrodes. We found that dissolved oxygen penetrates to a depth of ~1.5 cm in the sediments, similar to oxygen profiles measured during the 1980's in the same area (Traub, 1985, MSc thesis). We show that oxygenic re-mineralization of organic matter releases substantial amount of  $\text{CO}_2$  into the interstitial water. The observed pH drop in the upper few millimeters of the cores was however, smaller than expected by the magnitude of observed oxygen drop. This indicates that the expected pH drop was partially buffered by dissolution of sedimentary  $\text{CaCO}_3$  by the addition of  $\text{CO}_2$ . The phenomenon of  $\text{CaCO}_3$  dissolution due to organic matter oxidation suggests that under enhanced eutrophication conditions in relatively shallow seas, dissolution of  $\text{CaCO}_3$  in the bottom sediments is likely to occur. This is despite the highly supersaturated bottom water with respect to either calcite or aragonite ( $\Omega_{\text{Arag}} > 3.5$ ). The elevated alkalinity of the bottom water will cause it to release less  $\text{CO}_2$  to the atmosphere during the next winter vertical mixing. Such processes in shallow seas may have important implications for the ability of the ocean to sequester anthropogenic  $\text{CO}_2$ .

## Anthropogenic Changes Detected in the Recent Sediments of the Gulf of Eilat (Aqaba)

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Anthropogenic pollution sources in the Gulf of Aqaba (GOA) include sewage discharge from Aqaba and Eilat (Until 1985 & 1995 respectively) and aquaculture at the northern end of the Gulf (1989-2008). The estimated nutrient input from Eilat sewage was 150 ton N annually while the fish farms added 250 ton N and 50 ton P annually. These nutrient sources increased primary productivity in the northern GOA by a factor of 2.5 compared to the 1970's. In parallel the composition of planktonic foraminifera in the water column has changed, and *Globigerinoides sacculifer*, which was the dominant species until the early 1990's, has disappeared while *Orbulina universa*, a relatively rare species, became more abundant. The goal of this study is to track the anthropogenic changes in the sediments of GOA during the last few decades. For this purpose three short cores were taken out from a depth of 500 and 700 meters in northern GOA. The analysis of the planktonic foraminiferal assemblages showed that the disappearance of *G. sacculifer* and the increase in *O. universa* occur at a depth of ~5 cm, suggesting an average sedimentation rate of ~2.25 mm/y. The organic carbon increases over the top 6-8 cm, and its  $\delta^{13}\text{C}$  decreases by 1.5 ‰, this may be attributed to the fish farm period. In addition there is an overall decrease of  $\delta^{13}\text{C}$  along all the cores over the top 20-25 cm of about 2 to 2.5‰. This isotopic change may be related to the increased anthropogenic  $\text{CO}_2$  emissions due to its lighter  $\delta^{13}\text{C}$  composition and also to the higher fractionation of algae under increased  $\text{CO}_2$  levels.

## Anthropogenic platinum group metals (PGM) levels and their distribution in Israel

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Since 1993, automobile exhaust catalysts are compulsory in Israel, which obviously lead to a great improvement in the emission of toxic gases to the atmosphere. However, as they contain Rh, Pd and Pt, which belong to the platinum group metals (PGM), their utilization has introduced a new contamination source to the environment. For characterizing the extent of PGM distribution in Israel, road side soils were examined in locations adjacent to main roads: two along the Tel-Aviv – Jerusalem road (road #1) and two in the north of Israel (roads #6 and #65). In all sites, Pt concentrations in soils were relatively low compared to typical concentration levels in the environment [1] (mostly up to 20 ng/g) and could be detected only in surface samples while Rh concentrations were below limit of detection (10 ng/g). Higher PGM concentrations were found in surface samples containing a mixture of soil and dust. In addition to soils, road dust collected along a half km inclined part of the Jerusalem – Tel-Aviv road, yielded very high concentrations of both Pt and Rh ranging from 260 to 1480 ng/g and 80 to 440 ng/g, respectively. A remarkable difference between the two sides of the road at each location was observed. Road dust from uphill sites yielded concentrations which are 4-fold higher than on the downhill side for both Pt and Rh, indicating significant rise in PGM emission with increased engine activity. Elevated trace metal concentrations of traffic related metals (Cr, Cu, Ni, Pb and Zn) were noted for the road dust samples. However, only Zn concentrations exhibit a positive correlation with Pt and Rh concentrations and display a distinct 2-fold enrichment in the uphill direction probably due to tire friction. On a plot of  $^{208}\text{Pb}/^{206}\text{Pb}$  vs.  $^{206}\text{Pb}/^{207}\text{Pb}$  along with potential Pb sources, all samples are slightly shifted from a mixing line between the known Pb IC petrol values used in Israel and natural sources. No systematic hill slope pattern was observed. The slight shift of data points from mixing suggests an additional yet undefined, anthropogenic source. Deducing from the isotopic composition and high Pb enrichment factors, the contribution of natural Pb to these samples is minor. Hence, while PGM metals and Zn exhibit current contamination, Pb probably represents re-suspension of dust and soil surfaces that still carry the pre-unleaded petrol signature.

[1] Rauch & Morrison (2008) Environmental relevance of the platinum-group elements. *Elements*, 4: 259-263.

## Characterizing the process and quantifying the rate of subaerial rock weathering on desert surfaces using roughness analysis

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Subaerial weathering of rocks is a common process observed on desert surfaces, which has been previously identified as a key erosion agent driving geomorphic surface evolution and the development of desert pavements. And yet, fundamental aspects of the process, such as the relative contribution of the different weathering modes that drive it (e.g., mechanical breakdown, chemical weathering, aeolian abrasion) and the possible dominance of one of them, as well as the rate by which this process occurs, have not been systematically examined. Here, we present a new quantitative approach for addressing these aspects of process geomorphology. We focus on co-genetic desert alluvial surfaces of different ages (alluvial chronosequences) which provide excellent recorders for the evolution of boulder-strewn surfaces into smooth desert pavements through in-situ subaerial weathering of rocks. Our approach combines independent measures of two surface attributes: High resolution 3D ground-based laser scanning (LiDAR) of surface micro-topography, and numerical dating of surface age. Roughness analysis of the LiDAR data in power spectral density (PSD) space allows us to characterize the geometric manifestation of rock weathering on the surface and to distinguish between different weathering modes. Numerical age constraints provide independent estimates for the time elapsed since the process began. Accordingly, we are able to constrain surface roughness evolution on alluvial fan desert chronosequences through time, and present PSD analysis as a new quantitative tool to examine the process of subaerial rock weathering in desert environments. In this study we present results from two late Quaternary alluvial chronosequences along the Dead Sea Fault in the hyper-arid Negev desert of southern Israel. LiDAR scanning was applied on representative areas (~30-50 m<sup>2</sup>) of 10 separate surfaces ranging from rough Holocene surfaces to fairly smooth surfaces with well-developed pavements displaying an OSL age of 87 kyr. We find typical and recurring time-dependent changes in the offset as well as shape of the PSD curves in both chronosequences: PSD offset is continuously reduced over time reflecting the overall reduction of roughness at all wavelengths. The PSD curves display progressive moderation of slopes at the longer wavelengths with the moderation point itself systematically shifted to shorter wavelengths. This characteristic evolution of PSD offset and slope moderation at longer wavelengths

reflects the typical break up of boulder-sized clasts through time as the surfaces mature into well-developed desert pavements and points towards mechanical breakdown as the dominant weathering mode. In addition, we are able to determine the rate by which the larger clasts are removed from the system. We build on these new insights into process and rate of rock weathering to propose PSD analysis of surface roughness as a complementary method for constraining the age of desert alluvial surfaces in places where 'conventional' dating cannot be applied.

## Homogenization and Multi-Scale Analysis of Geomaterials with Inclusions

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Various geological materials are comprised of stiff inclusions embedded in softer matrix: conglomerates, gravelly soils and concrete among others. Moreover, the typical scales of the constituents are different by orders of magnitude from microscopic to macroscopic. In this research we apply the homogenization theory to study, using FEM, the elastic properties of geo-materials with inclusions. Specifically we study the applicability of an isotropic material model to geomaterials with inclusions and the deviation of this model from a general anisotropic material model. First we present a parametric analysis aimed to study the influence of volumetric fraction, shape and inclination of inclusions on the effective material matrix. The results are compared with the effective elastic constants calculated from general mixing laws. Next we present a multi-scale analysis of the Sde-Zin polymictic conglomerate (Pleistocene), which consists of four consecutive homogenizations for calculation of the elastic constants for this heterogeneous rock unit. We conclude with general recommendation for estimation of elastic constants geo-materials with inclusions.

## Thermal evolution, uplift and Erosion of the Negev (Red Sea rift margin) during the last 100 Ma: Low-temperature thermochronology of deep boreholes and igneous outcrops

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Lying at the margin of the Red Sea rift and the Dead Sea fault and at the locus of intense Late Cretaceous regional folding - the exhumation, uplift and cooling record of the Negev (southern Israel) holds answers to the timing, rates and mechanisms of major tectonic events including the closure of the neo-Tethys ocean and the associated evolution of the Syrian Arc fold structures, continental rifting along the Red Sea, regional Oligo-Miocene denudation phase and the development of the Dead Sea fault. We utilize low-temperature thermochronology to examine the cooling history of the Negev during the last ~100 Ma as reflected in (U-Th)/He apatite ages of samples collected from deep boreholes and Early Cretaceous igneous outcrops. Since the maximum exhumation depth across the Negev during the last 100 Ma rarely exceeds ~1.5 km, the apatite He system is an ideal thermochronometer for this setting. Samples from 6 deep boreholes reaching depths of up to ~3.5 km and penetrating a Neoproterozoic stratigraphic sequence (Zenifim Formation) at their base are currently being dated. Initial (U-Th)/He ages from Ramon 1 borehole decrease from ~105 Ma at the surface to ~1.5 Ma at a depth of ~3.5 km where the current temperature is ~90°. Previously published apatite fission track ages from the same borehole decrease from ~120 Ma to ~33 Ma. Preliminary thermal modeling of Ramon 1 borehole data delineate rapid cooling at the Late Cretaceous (commencing at ~95 Ma). This cooling phase, which is far more significant than the Oligocene-Miocene cooling following the initiation of the Red Sea rift and Dead Sea transform, is probably a reflection of intra-continental deformation associated with growth of monoclines in response to convergence between Africa-Arabia and Euroasia plates and the closure of the Neo-Tethys ocean. We also explore the possibility that a fraction of the observed cooling signal is related to thermal relaxation of a hot lithosphere following earlier magmatic activity. Relatively old (U-Th)/He cooling ages observed in samples held at high temperatures (70-90°) for >45 Ma appear to support radiation damage effect on helium diffusion and enable to calculate the effective diffusivity of Helium in apatite. We discuss the observed decrease in (U-Th)/He ages as a function of borehole temperatures relative to the pattern observed at the KTB borehole in Germany and boreholes in the Otway basin in Australia.

## Quantitative submarine/seismic geomorphology (QSG) project – collaboration between Statoil AS and the University of Bergen, Norway

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Quantitative submarine/seismic geomorphology (QSG) is a new direction in the application of geomorphologic knowledge and techniques seismic data analyses that has already generated a considerable change in our knowledge and characterization of buried clastic environments. QSG is defined as a quantitative analysis of landforms, imaged in 3-D seismic data, for the purposes of understanding the history, processes, and fill architecture of basins through the collection and analyses of quantitative data on sequence morphometrics, and their spatial and temporal variability. The techniques integrate seismic investigation, visualization and extraction of seismic attributes, geobodies and geological structures, GIS and statistical analysis. This project is funded by Statoil AS and performed in close collaboration with the Clastic Plays and Reservoirs Department in Exploration Research, R&D, Statoil AS. It incorporates both bathymetric and high resolution 3-D seismic records, and covers passive (e.g. US Atlantic) and active (e.g. US Pacific), high-latitude (e.g. Gulf of Alaska) margins, and salt-constrained areas – off Angola and Brazil. The data analysis includes small (hundreds of sq. km) and large (thousands of sq. km) data sets to allow the harvesting of morphometric data on various elements of the explored domains. Relationships derived from modern bathymetry-based data are used not only to ascertain relationships between geomorphological characteristics of the fairways but also to assist in understanding spatial distribution of reservoir elements derived from high-resolution 3D seismic datasets. Moreover, quantitative morphologic data, measured from subsurface domains, allow reexamination of the empirical relationships among system elements. Application of quantitative seismic geomorphology to existing data volumes around the world has shown the potential to provide a heretofore unrealized dense, deep, and spatially extensive understanding of older geomorphologic frameworks of the world enigmatic geological provinces.

## 1.5°C global warming – a tipping point for permafrost thawing: lesson from 1.1 million-year speleothem record in Siberia

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Permafrost regions (in which the ground is frozen throughout the year) cover 24% of the northern-hemisphere land surface and hold ~1700 Gt of organic carbon. When it thaws it releases CO<sub>2</sub> and CH<sub>4</sub>, turning a long-term carbon sink into a source, creating a positive feedback during greenhouse warming. Therefore an ability to predict the extent of future permafrost degradation is desirable. We used speleothem records of Siberian caves to investigate 1.1 million year history of Siberian permafrost. Vadose speleothems (stalactites, stalagmites, and flowstones) form when meteoric waters (i.e., originating from atmospheric precipitation) seep through the vadose zone into caves. Cave temperatures usually approximate the local mean annual air temperature, and when they drop below 0°C the rock above and around the cave freezes, and speleothem growth stops. Therefore speleothems found in the caves located in permafrost regions are relicts from past periods with climate warmer than present. Accurate and precise dating of deposition periods of these speleothems by U-Th and U-Pb techniques shows when permafrost was discontinuous or absent, allowing water seepage into the cave. Ledyanaya Lenskaya Cave, Eastern Siberia (60°22'N - 116°57'E), is located in continuous permafrost region, close to its boundary, with no present-day speleothem deposition. New U-Pb chronology results of speleothems from Ledyanaya Lenskaya Cave, Eastern Siberia, show substantial speleothem deposition around 1 million years BP. A later period of speleothem deposition occurred at Marine Isotopic Stage (MIS) 11 around 400,000 years ago (1). Both episodes of permafrost degradation occurred when global temperatures increased 1.5±0.5°C above the pre-industrial level (2), showing that this degree of warming is a tipping point for continuous permafrost to start thawing. Today, global temperatures are already ~0.7°C above the pre-industrial level, and climatic models agree that warming of 1.5±0.5°C will be achieved within 10-30 years (3). Therefore an urgent global effort of reducing emissions of greenhouse gases is required.

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## Review on oil shale production activities worldwide.

**Volin S.<sup>(1)</sup>, Shitrit D.<sup>(1)</sup>**

1. Rotem Amfert Negev

There are only a few countries in the world, which actually produce oil and energy from oil shale. Those countries are China, Brazil, Estonia and Israel. Estonia represents about 70% of the oil shale production in the world and, in fact about 90% of the energy needed in that country is produced by oil shale.

There are two main methods used for oil shale energy production:

1. Direct oil shale combustion, which burned the oil shale rock, similar to coal burning in a power plant.
2. Oil shale retorting- this method utilizes kerogen feature (which is the main component of the organic material in the rock) in pyrolysis process (heating in the absence of oxygen) to decompose into crude oil and gas.

The tendency in the world is to adopt the retorting process since it is considered less pollutant than direct combustion, since the process occurs at relatively low temperature, around 5,500 c. At these temperatures no calcite decarbonization occurs and therefore less CO<sub>2</sub> is emitted into the atmosphere, in comparison to direct combustion at higher temperatures in which most of the gases are emitted from the calcite decarbonization. The oil yield is the main quality of the oil shale rock. The yield index is called the Fischer assay. Estonia is known for its high oil shale quality, and can produce 125 kg of oil per ton of oil shale rock. Israel for example can theoretically produce about 70 kg of crude oil per ton of oil shale rock. In terms of oil barrels (containing 159 liters per barrel) there is need approximately 2.5 tons of Israeli oil shale to produce one barrel. As of 2011 the world's oil shale industry produced approximately 9.0 million barrels annually, in addition to mining of oil shale rocks in order to produce electricity (direct combustion).

## Exposure of the Arabian plate during the Oligocene, evidence from Bet She'an basin, Northern Israel

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Exposure of the Arabian plate during the Oligocene induced widespread erosion. Products of the erosion were transported to the nearby Levant basin, leaving only scarce outcrops across northern Israel. Interpretation of seismic reflection and borehole data across Bet She'an basin, eastern Galilee, reveals a ~250m thick, probably detrital, section of Oligocene age. This section covers the northeasternmost flank of the Cretaceous Syrian Arc fold belt and thickens toward the Mesopotamian basin in the east. Progradation sets within the section resemble a typical clastic pattern across a continental margin. We deduce that the section accumulated upon the mildly elevated Shomeron high, which divided between the Mesopotamian and the Levant basins.

## The impact of pyrolysis processes on the geochemical and mineralogical composition of oil shales from the Shefela basin

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The Israeli oil shales contain substantial concentrations of heavy metals, which correlate with the organic matter and clay content. In-situ retorting of oil shales, which includes underground heating of the oil shales and pumping out the liquids and gases, may lead to the release of such metals and their migration to groundwater, depending on the nature of the metals bound to the rock constituents. The main goals of this study are first, to characterize the composition of the oil shales, concentration of various elements and heavy metals and their association with different constituents in the rock, and second to understand the geochemical changes in the oil shale rocks as a result of the pyrolysis process and estimate the redistribution and mobility of various heavy metals in the residual rock. The background composition of the oil shales in the Shefela basin was studied utilizing through ten samples taken from cores of two wells, Nahal Govrin and Aderet, which were drilled in 2010 by IEI Company. The contents of the major, minor and trace elements were measured in all samples. The associations of the trace elements to the various solid components of the rock are evaluated through a Selective Sequential Extraction (SSE) method and the correlations between major and trace elements were evaluated. The oil shale sequence is characterized by four mineralogical phases: organic matter (9-20%), calcite (42-61%), apatite (2-4%) and clay minerals (6-23%). High concentrations were found for Ba, Cr and Zn (100-500 ppm), and for Sr (~1000 ppm). A positive correlation was found between the concentrations of the elements B, Be, Ce, Co, Cr, Cs, Li, Pb, Rb and Th and the clay mineral content. The effect of pyrolysis on the oil shale composition was examined by a set of pyrolysis experiments with variable heating and pressure conditions performed on the same set of samples which were previously studied. The geochemical and mineralogical composition of oil shale samples before and after the pyrolysis process were compared in order to understand the changes in the chemical composition of the rock following pyrolysis. Preliminary results show that the concentration of Al, Si and P was significantly increased after the pyrolysis due to material loss. The concentration of S was significantly decreased in the residual rock due to its volatilization during the pyrolysis process.

## Silicates dissolution during interaction with sea-water and its potential contribution to the isotopic composition of Sr in the oceans

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The isotopic composition of Sr ( $87\text{Sr}/86\text{Sr}$ ) in the oceans is known to fluctuate since the beginning of the phanerozoic eon, reflecting the mixture between riverine input of weathered rocks and hydrothermal exchange in mid-ocean ridges. Theoretically, interaction of seawater with sediments at the ocean floor can release Sr to the water hence altering its Sr isotopic composition. Though numerous laboratory based experiments used many different type of solution to study the dissolution of various rocks and minerals, only one used sea water as the interaction solution. In the present study, the dissolution of albite, k-feldspar and of silicate-rich alluvial sediment during interaction with synthetic seawater is studied by tracking the changes in water chemistry and in  $87\text{Sr}/86\text{Sr}$  ratio. Alluvial Sediments from streams that drain single homogenous silicate-rock unit exposed in Eilat Region along with Albite and K-Feldspar were sampled and prepared for batch dissolution Single-Point experiments (SPB). In these experiments, synthetic seawater was used in order to avoid present ocean water Sr background. In addition, a Borax-HCl solution with similar pH value (8.2) but with much lower ionic strength was used. Periodically, the solution was separated from the sediment and was analyzed for Si, Al, Sr, Ca, Mg and K concentrations as well as for pH and  $87\text{Sr}/86\text{Sr}$  ratio. Preliminary results indicate that the calculated dissolution rate of Albite by sea water is of the order of  $1.5 \cdot 10^{-15} \text{mol/sec} \cdot \text{gr}$ , which is  $\sim 50$  lower than estimated by Knauss and Wolery (1986) under the same temperature and pH. For Albite dissolution, while the Sr concentration increased with time, the isotopic composition decreased suggesting a two end-members mixing line. The initial high value contribution of Sr is probably from traces of apatite, which is known to dissolve two orders of magnitude faster under the current experiment conditions. When comparing the use of Borax-HCl versus that of sea water as interacting medium, the release rate of Si in Eilat Granite and Roded Quartz-Diorite using Borax-HCl and sea water solutions show a strong catalytic effect for Borax-HCl which causes a  $\sim 2$  times release rate compared to sea water during the first week of experiments. Later on, only the Eilat Granite shows a significant higher apparent dissolution rate in the Borax-HCl solution, with a Sr release rate  $\sim 4$  times higher than in the SW solution. To conclude, this study shows that dissolution of silicates grains occurs as they come in contact with seawater where Sr is also released to the seawater.

## Paleoseismology in the Western Wall Tunnels – who Quakes the Vaults?

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Evidence for seismically induced damage are preserved in historic masonry structures at the Western Wall Tunnels complex, below the Old City of Jerusalem, possibly one of the most important tourist attractions in the world. In the tunnels, structures dated to 500 BC and up until modern times have been uncovered by recent archeological excavations. One of the interesting findings is a 100 m long bridge, composed of two rows of barrel vaults, believed to have been constructed during the 3rd century AD, and serviced the traffic between the Temple Mount and the western city Mount Zion. In one of the vaults a single masonry block is displaced 7 cm downward with respect to its neighbors. Results of dynamic numerical simulations suggest that the damage observed at the vault was induced by seismic vibrations that must have taken place before the bridge was buried underground, namely when it was still in service. We find that the peak ground acceleration (PGA) required for causing the observed damage was high – between 1.5 and 2 g. The PGA calculated for Jerusalem on the basis of established attenuation relationships for historic earthquakes that struck the region during the relevant time period is about one order of magnitude lower: 0.14 and 0.48 g, for the events that took place at 362 and 746 AD, respectively. This discrepancy is explained by local site effects that must have amplified bedrock ground motions by a factor that can reach up to values of 10. This result clearly illustrates the significance of incorporating local site effects when assessing the seismic risk associated with specific regions in general, and particularly in cities where soft layers separate between the bedrock and the ground surface.

## Climatic Conditions During Human Occupation in Middle and Upper Paleolithic in the Western Galilee, Israel Based on U-Th Dating of Speleothems from Manot Cave

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Manot Cave is a relict karst cave rich in speleothems, located in the Western Galilee, Israel. The recent discovery of Manot Cave in 2008, revealed the presence of a rich archaeological record. The lithic assemblage indicates that it was occupied from the Middle Paleolithic through the Epipaleolithic (250-15 ka BP) and mostly during the Upper Paleolithic (45-22 ka BP). In addition to stone tool artifacts and animal bones, a part of what was identified by Prof. Israel Hershkovitz as modern human skull (calvaria) was discovered (probably not in situ) in one of the cave's inner chambers. When the cave was not occupied by humans, it was used by carnivores. Some of the lithic assemblages are sealed by flowstone layers in several areas inside the cave, or are covered by carbonatic crust in others. These relationships between archaeological artifacts and speleothems enable the determination of the time range of the human occupation inside the cave, using U-Th decay series dating on the speleothems. U-Th ages of the carbonate associated with archaeological remains span the time interval between ~60-30 ka BP, time span that partly covers the period of the great migration out of the African continent, according to the "Recent-African-Origin-of-Modern-Humans" hypothesis (also referred to as the "Out-of-Africa" hypothesis). The speleothem record indicates that their growth stopped ~30 ka BP, associated with cold Heinrich (H) event H3. The ceasing of the speleothem growth mark a break in human occupation inside the cave. The study in Manot Cave therefore can shed light on one of the open questions in human evolution: the dispersal pattern of modern humans through the Levant into Europe and the climatic and environmental conditions early modern humans were facing in the region.

## Eilat Fault Revisited - Results of a Seismic Survey

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The Geophysical Institute of Israel conducted a 2D seismic reflection survey at the port of Eilat in order to confirm the presence of an assumed active fault mentioned in the GSI Fault Map (2010) and Earthquake Catalog (2012), possibly existing under the future expansion of the port. The work premise was that if the fault is near or under the port, its direction would be North-North-East to South-South-West and therefore the lines were planned to be perpendicular to it, as locating the fault with two parallel seismic lines would confirm its existence. The survey was ordered by the Israel Ports Company and included two seismic lines with a total length of 1380 meters, recorded during December 2012. Both lines were in the East-West direction and included both marine and land segments for each line. The survey results cover an area of up to 350 meters from the shore line. The seismic survey was conducted using the reflection seismic method, which is used in order to create an image of the subsurface. The method is based on the insertion of P-waves to the subsurface while monitoring the first arrivals of reflections caused by acoustic impedance contrasts between layers with different elastic properties. The reflected waves are received by an array of sensors and are recorded in a multi-channel recording system. The data is then processed in order to create an optimal seismic time section, which is used as a basis for geophysical interpretation, together with well logs and surface maps. The lines were then processed in the GII Processing Center. The results of this survey showed time sections with no evidence of an existing fault running along the shores of the Eilat bay despite earlier assumptions to the contrary.

## Should the soil amplification factors, defined by NEHRP (USA), be implemented in the Israel building standards?

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Seismic wave amplification in soft deposits has contributed to damage and loss of life in almost all recently documented damaging earthquakes. It is often observed that the resonant periods of urban structures are close to those of the soft layers upon which many towns are built. Thus, reliable assessment of the frequency dependent site amplification effect is very important for safe design of buildings. The National Earthquake Hazard Reduction Program (NEHRP) recommended provisions for seismic regulations for new buildings and other structures and have provided a scheme for classifying sites according to the average shear wave velocity through the top 30 m of a soil profile,  $V_{S,30}$ , and associated the soil classes with site amplification factors  $F_a$  for short period (0.2 sec) and  $F_v$  for long period (1.0 sec). The soil classification scheme and the values of  $F_a$  and  $F_v$  are used in many National Building Codes including Israel Standard (SI 413, provisional amendment 5). The geological conditions in many areas in Israel may vary dramatically over distances as small as 200 m or less and consequently will yield great differences in site amplification effects. Rapid changes in the geological set-up can easily be detected by analyzing measurements of ambient seismic noise. The differences in the local geology down to the base-rock will be responsible for significant differences in ground motions between sites of the same soil cover and similar distance from an earthquake source. If we would like to adopt the concept of using correction values to design the site specific acceleration response spectrum, than we have to look for a more complex way to classify the site. The use of a single parameter  $V_{S,30}$  is a simplification that cannot be justified in the complex geological conditions as in many Israeli sites.

## Using nitrogen isotopes to follow the nitrogen cycle in the Lake Kinneret

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Lake Kinneret receives its nitrogen from natural and anthropogenic sources. Understanding the nitrogen cycle will allow differentiating between the relative contribution of each component and their effect on the processes occurring in the lake water. This study focuses on the sources and dynamics of dissolved nitrogen species in Lake Kinneret, and their relations to the seasonal variations and the limnological cycle. Accordingly, seasonal depth profiles were taken and the concentration and isotopic composition of nitrogen of the dissolved inorganic species – nitrate ( $\text{NO}_3^-$ ), nitrite ( $\text{NO}_2^-$ ) and ammonium ( $\text{NH}_4^+$ ) were measured.

Preliminary results, following the seasonal variations between December 2010 and August 2011, show that nitrate concentrations increase continuously from December till March-April. This increase is attributed to nitrification of ammonium in the mixed and oxidized water column. During this time period, the ammonium concentrations decrease to nearly zero. An additional source for the increase of nitrate in the spring season is runoff streams which flush large amounts of nitrate to the lake. In the summer season, the nitrate concentrations decrease gradually till its near disappearance in late summer. One of the open questions is whether the “disappearance” path of the nitrate is due to its consumption by algae that fix particulate organic nitrogen which deposit to the bottom of the lake, or is due to slow diffusion of epilimnetic nitrate to the anoxic-reduced bottom water layer and in the sediments, where denitrification may occur. The variations in the nitrate concentrations are associated with seasonal variations in the isotopic composition of its nitrogen and oxygen. Nitrogen isotopic composition during the winter season is around 6 permil, increasing to about 9 permil during the spring, reaching a maximum value of 10-11 permil in the summer. The nitrification of ammonium during the winter season is accompanied by isotopic fractionation, resulting in lower isotopic values of the nitrate product relative to the ammonium source. During the winter season, nitrogen isotopic values of the ammonium are about 15 permil higher than those of the nitrate. The nitrate in the surface runoff during this season is characterized by isotopic composition similar to that measured for the nitrate in the winter season of about 6 permil. To conclude, seasonal variations can be characterized and can be explained by the relative abundance of the nitrogen species, and by their isotopic composition.

## Amazonian affinity of the oldest metasediments of SE Europe: the Pelagonian Zone (Greece)

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The land mass bordering the northern flanks of the Eastern Mediterranean is made of a collage of diverse continental terranes that were primary formed on the Neoproterozoic active margin of Gondwanaland, as a part of extended (ca. 6,000 km) realm of the Avalonian-Cadomian magmatic arc. Most studies concentrated on their Alpine and younger evolution, while the origin and the earlier geological history of the crystalline basement units is less studied and remain enigmatic. Here we report the isotopic properties of a major terrane in the Alpine edifice of the Eastern Mediterranean - the Pelagonian zone of the Hellenides, Greece. The Pelagonian has been shaped by Neoproterozoic (700 Ma) and Variscan (300 Ma) igneous activity that penetrated an earlier basement of uncertain age and origin. In the present study, detrital zircon U-Pb geochronology and Lu-Hf isotope geochemistry of detrital zircons extracted from pre-700 Ma Pelagonian metasediments and from magmatic zircons from 700 Ma-aged granitic plutons allow for the first time a genuine perspective into the provenance and origin of one of the oldest sedimentary sequences known in SE Europe. According to the obtained isotopic data, the Pelagonian basement possesses an Amazonian affinity, and exhibits close similarity to the "old basement" which underlies typical Avalonian successions in Atlantic Canada. Terranes imbricated with the Pelagonian zone in the Eastern Mediterranean region (i.e. Attico-Cycladic Massif, Serbo-Macedonian Massif, the basement of External Hellenides exposed in Crete and the Taurides basement of Anatolia) yield very different detrital signal, indicating derivation from North Africa (N. African detrital signal is typically devoid of Mesoproterozoic ages). On the other hand, the Pelagonian zone differs from Amazonia-derived terranes in the region (Istanbul block of the Pontides, Pirdakikia terrane of the Internal Hellenides, Dobrogea terrane and Danubian basement, which contain abundant Mesoproterozoic-aged zircons): these terranes exhibit evidence for intensive Avalonian (ca. 570-520 Ma) magmatism, which is absent from the Pelagonian basement. This renders the Pelagonian zone exotic relative to the surrounding terranes of North African origin, as well as relative to Avalonian-type terranes located in the Eastern Mediterranean.

## Pollution History of Trace Metals at the Coastal Plain of Israel reconstructed from Sediments of the Dora Winter Pond (Netanya)

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The coastal plain, the most populated area in Israel, has been exposed to contaminating trace metals since the beginning of industrialization. The working hypothesis was that sediments of relict coastal wetlands are an effective contamination recorder, as metals reaching the pond, via airborne particles and terrestrial run-offs, will tend to be sequestered in the sediment due to their affinity to depositing organic matter, oxides and fine minerals. Indeed, sediment from the Dora winter pond (Netanya) enabled reconstructing its pollution history based on concentration profiles of Pb and other trace metals, Pb isotopic composition (Pb IC) and <sup>210</sup>Pb dating. In a 40 cm core from the center of the pond, the concentration of Pb peaked in the late 1980s - early 1990s, with a ~17-fold increase above background levels, constituting the largest anthropogenic impact compared to the other trace metals in the profile. Lead and other trace metals (e.g., V, Zn) started rising remarkably at the end of the 19th century. The Pb IC indicates petrol-Pb is probably the main Pb source in the last century, as <sup>206</sup>Pb/<sup>207</sup>Pb values at the upper part of the profile corresponds to petrol-Pb end members, while the lower part of the profile is very different and attaining a narrow range of higher values (around 1.20), corresponding to natural Pb sources. Indeed, the Pb concentration profile is highly correlated with calculated Pb emissions that originated from petrol combustion in Israel, including imprint of the introduction Pb additive to petrol in the 1920s' and the maximum calculated petrol-Pb emissions in the late 1980s'. The sediment layer, where the beginning of new trends of Pb concentrations and IC are recorded, is dated to the end of the 19th century, correlative to the beginning of a demographic change in Israel that was accompanied by a significant increase in land use and industrialization. Yet, the significant change in Pb IC from natural background levels is noted earlier, implying anthropogenic Pb input to the Israeli atmosphere from other sources. Altogether, the sediment from the center of the pond enabled reconstruction of the anthropogenic pollution history, possibly of wide-scale significance. Modern petrol-Pb pollution is also the main contamination source to the sediment from the southern and northern margins of the pond as indicated by the Pb IC. However, the trace metals concentrations correlate strongly with buried organic matter and

fine grains, implying the sediment contamination record is impacted by fallout of Eucalyptus trees at the perimeter of the pond, delivering pollution, probably more from adjacent neighborhoods and roads.

## The Deformation of the 'Salt Mirror' and the Uplift of Mount Sedom

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While scientific knowledge of salt tectonics is vast, less is known regarding the specific internal movements of the salt units that build salt extrusions such as Mount Sedom salt diapir. The deformation within the internal salt units and their relation to one another is hardly understood. In this study we focus on the recent deformation processes of southern Mount Sedom. The top of the rising diapir underwent dissolution by ground- or lake-water and the accumulated residual hardly-soluble matter formed a caprock. The flat, near-horizontal, contact between the almost-vertical salt layers and the caprock is referred to as the 'Salt Mirror'. Since its fossilization at ~14 ka, the Salt Mirror has undergone distortion and tilting representing the ongoing internal movement of the salt units. Accordingly, the Salt Mirror can be used to understand and define the deformation processes that had taken place within, and between, the different salt units. To do so we are mapping out the Salt Mirror surface in outcrops and caves throughout the region. The potential data that can be acquired within these caves, that contain approximately 60% of the research area data, is necessary for completion of the full layout of the Salt Mirror throughout the diapir. The resulting structural map of the Salt Mirror can be analyzed and cross-referenced with data from earlier studies. We assume that the structure of the Salt Mirror reflects the ongoing deformations within, as well as the interactions between, the salt units since the early Holocene. More specifically, we test whether the topography of the Salt Mirror is similar to that of Mount Sedom. The answer to this question is acquired by analyzing the maps of these surfaces. Point elevation data are plotted on a diagram looking for a linear fit confirming structural similarity. Initial results indicate that some areas around the mountain present stronger correlation between the structure of the Salt Mirror and the structure of the diapir upper surface than other areas. Our current database is not yet sufficiently wide and the accuracy of surface topography is not adequate. Both of these issues will be addressed in the future research. Understanding the processes in Sedom diapir will enrich the knowledge of diapir development not only on Mount Sedom but worldwide.

## Quantification and Modeling of Land Degradation using Terrestrial Laser Scanning in Tziporim in the Negev Highlands

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Land degradation frequently occurs during alterations in regional geomorphology resulting from climate change or shifts in land use. Its effects on arid and semi-arid regions are dominantly characterized by massive soil erosion and large changes in biomass. Runoff from heavy rains drives the development of erosional headcuts developed in loessic soils that originated from desert dust. As soil is lost, more bedrock is exposed, contributing to increased amounts of runoff. The diversion of runoff into gullies affects the amount and variety of vegetative cover. This trend of positive feedback accelerates the degradation of the land. Tziporim, a valley in the Negev Highlands, is representative of the regime of land degradation undergone in semi-arid environments. Previous methods to study these processes have been rudimentary in nature. Use of a terrestrial laser scanner (TLS) enables us to capture the fundamental mechanisms that drive erosion and to quantitatively describe its consequences on the vegetation. We have collected 3 TLS datasets from a backwards migrating erosional headcut in Tziporim: Winter 2009, Spring 2010, and Winter 2012. Preliminary data processing includes co-registering different epochs, filtering of on- and off-terrain data, and resampling. The on-terrain data forms the basis for soil erosion and gully research, while the off-terrain data is used to analyze changes in biomass.