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Ministry of Energy
and Infrastructure

**GEOLOGICAL SURVEY
OF ISRAEL**

**THE GEOCHRONOLOGY OF THE COVER BASALT:
REVISED K-Ar AND NEW $^{40}\text{Ar}/^{39}\text{Ar}$ RESULTS**

**Ariel Heimann, Gideon Steinitz,
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Report GSI/6/96
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ABSTRACT

The volcanism in northeastern Israel constitutes a part of an extensive, NW-SE trending, Cenozoic volcanic field ranging from the Dead Sea Rift area, western Syria, Jordan, to Saudi Arabia. Within this volcanic field, the most significant volcanic phase at its northwestern end, according to its volume and extension, is the Cover Basalt Formation. Locally, at the scale of northern Israel and of the northern part of the Dead Sea Rift, this unit forms the major Cenozoic volcanic unit.

One hundred and two (102) sites from the base, within and the top of the Cover Basalt section were dated using the K-Ar and $^{40}\text{Ar}/^{39}\text{Ar}$ methods. The overall age of the Cover Basalt unit is from 5.5 to 3.3 Ma. Based on the geochronological results the Cover Basalt unit appears to be a highly diachronic unit. The ages obtained for sites at the base of the sequence are 5.5-4.0 Ma, where sites from the top of the section were dated to 4.7-3.3 Ma.

תקציר

הוולקניזם בצפון-מזרח ישראל מהווה חלק מהשדה הוולקני הקנוזואי, שכיוונו צפון-מערב - דרום-מזרח, המשתרע מאזור בקע ים-המלח, מערב סוריה, ירדן ועד ערב הסעודית. הפאזה הוולקנית המשמעותית ביותר בשדה זה, על פי נפח החומר הוולקני ועל פי השתרעותו, היא בזלת הכיסוי, הנחשפת בקצהו הצפון-מערבי של השדה. בזלת הכיסוי חשופה בצפון מזרח ישראל - בגליל, בגולן, ובבקע ים המלח, ומהווה את היחידה הוולקנית הקנוזואית המשמעותית ביותר בישראל.

מאה ושניים (102) אתרים מבסיס חתך בזלת הכיסוי, מתוכו, ומחלקו העליון של החתך, תוארכו בשיטות K-Ar ו- $^{40}\text{Ar}/^{39}\text{Ar}$. גילה הכולל של בזלת הכיסוי הוא 5.5 - 3.3 מליון שנה. על פי נתוני הגיל של האתרים השונים של בזלת הכיסוי מסתבר שהיחידה דיאכרונית. גיל בסיס החתך הוא 5.5 - 4.0 מליון שנה, בעוד שגיל גג החתך הוא 4.7 - 3.3 מליון שנה.

INTRODUCTION

The volcanism in northeastern Israel constitutes a small part of an extensive Cenozoic volcanic field extending from the eastern Galilee, western Syria, through Gebel Druze, Jordan, to Saudi Arabia (Fig. 1). The eruptions in NE Israel started in the Miocene (some 18 m.y. ago) and continued, in several phases to recent times (e.g. Mor, 1986; Heimann, 1990; Shaliv, 1991). This volcanic field (Shamah), similar to others on the Arabian Plate (e.g. Khaybar and Rahat, (Camp and Roobol, 1989)), is aligned in a northwestern direction, subparallel to the Red Sea (Fig. 1). As such it constitutes a part of the Tertiary volcanic and tectonic pattern of the Arabian plate in the Middle East. The close geographic relations between the volcanism and the Dead Sea Transform is especially important for defining the tectonomagmatic relations and evolution along that transform plate boundary.

The Tertiary volcanic sequence in Israel is divided into three units:

- 1) The Lower and Intermediate basalts of Miocene age.
- 2) The Cover Basalt of Pliocene age.
- 3) Young basalts of Pleistocene age.

Within the northern Israel volcanic field the most significant volcanic phase, according to its volume and extension, is the Cover Basalt (Schulman, 1962) which is exposed on both sides of the Rift in northern Israel, as well as in southern Syria and northern Jordan. In northern Israel it occurs in the Golan Heights, the Korazim Block, southeastern Galilee, along the Sea of Galilee, in the Jordan Valley, the Bet She'an Valley, Harod Valley, in Mt. Gilboa, and Kokhav HaYarden (Fig. 2). In addition it was encountered in boreholes in this and adjacent areas.

The importance of the volcanic history of the Cover Basalt in northern Israel stems from:

- a) Its relatively wide distribution and its association and interfingering with continental sedimentary units which are developed in different continental settings in the area. The stratigraphy (and geochronology) of the volcanic units relates directly to these units, which are devoid of extensive faunistic and other stratigraphic controls.
- b) Its proximity, in time and space, to the Dead Sea Transform.

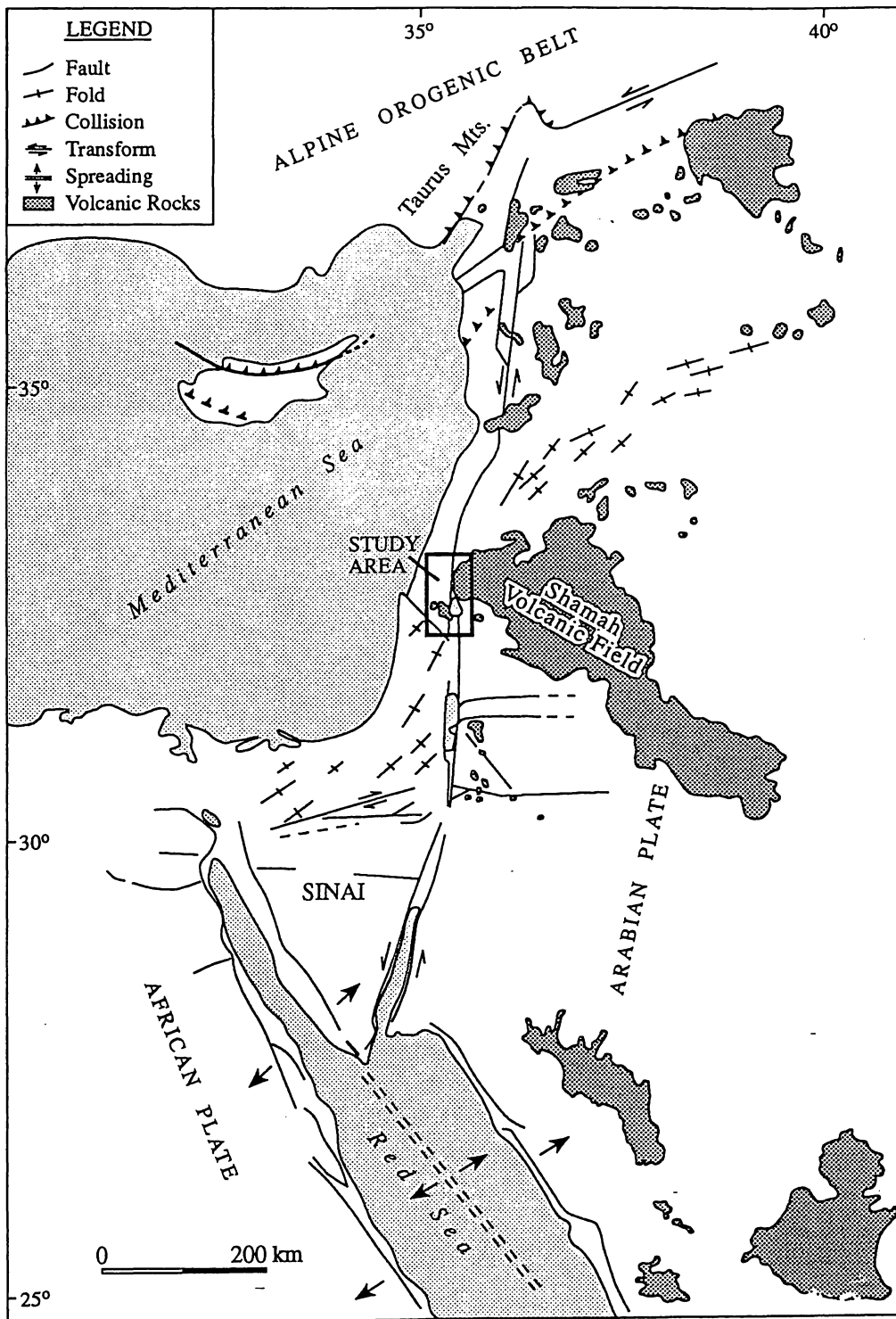


Fig. 1. General tectonic setting of Israel and adjacent areas including the volcanic fields (after Freund and Garfunkel, 1976).

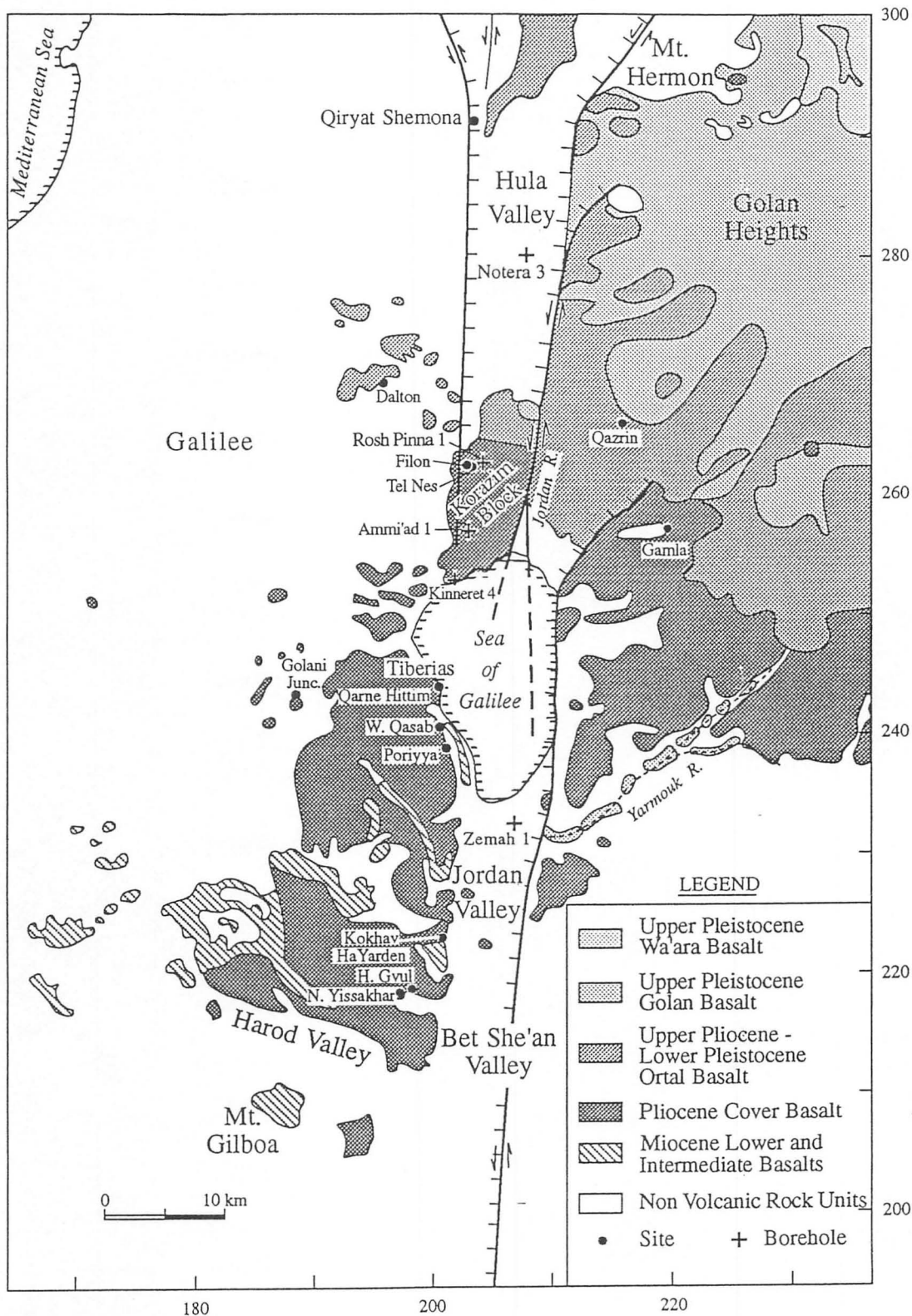


Fig. 2. Map of the volcanic units in northern Israel.

The age of the Cover Basalt was always of a major interest for the local geological community. The purpose of this paper is to summarize the previous dating, to present new $^{40}\text{Ar}/^{39}\text{Ar}$ measurements on a series of Cover Basalt outcrops and to present an updated evaluation for the age of the Cover Basalt.

GEOLOGICAL SETTING

The type section of the Cover Basalt is located between Nahal Yissakhar and Hirbet Gvul in the Lower Galilee (Fig. 2) where its thickness attains 150 m (Schulman, 1962). In other localities the unit reaches a thickness of up to 170 m. Using the present knowledge on its exposures, the type section defined by Schulman (1962) is probably not the most representative one. Thicker sections and ones displaying more flows are known mostly in the Golan.

The Cover Basalt (as the others Tertiary basalts in northern Israel) has chemical and mineralogical characteristics of alkali olivine basalt (Brenner, 1979). The most common phenocryst assemblages are olivine and olivine-augite. The average modal composition is 20% olivine, 30% plagioclase (usually An 60), 30% pyroxene, 10% cryptocrystalline material and 10% minor accessories. Chemically the basalts are characterized by relatively low silica, relatively high total alkalis, high K and high TiO_2 contents (Brenner, 1979).

In TAS (total alkalis to silica) diagram, the Cover Basalt from the Golan and the Dead Sea Rift falls within the alkali-basalt field, while the Cover Basalt from the Galilee are alkali-basalts to basanites (Weinstein et al., 1995). Increase in alkali concentrations coincides with an increase in the concentrations of incompatible elements like Nb, Ba and LREE (Weinstein in Heimann et al., 1995). Weinstein et al. (1995) suggested that the Cover Basalt is characterized by a high degree of melting (compared to the Lower Basalt of Miocene age), with the melting region underlying both sides of the Dead Sea Transform.

Sources for the Cover Basalt have been identified as lava cones and dykes. In the southern Golan five lava cones and three relicts of scoria cones were identified (Mor, 1986). In the Lower Galilee some dykes (e.g. Wadi Qasab dyke) and lava cones (as the one in Qarne Hittim) are known as sources (Fig. 2). In the Korazim Block two sources (Tel Nes and Tel Filon) were identified. Additional cinder cones were covered by later eruptions and are currently not exposed

(e.g. the cone in Nahal Daliot (near Gamla) that was covered and is presently exposed by the river cut [Mor, 1986]). The scarcity of sources identified in northern Israel is probably a result of erosion and/or covering by later volcanism. Very few feeder dykes are known, probably as a result of difficulties in distinguishing between the host rock and the dykes. The clearest exposures of dykes are known from localities where dykes cut the sedimentary sequence.

The Cover Basalt flows are typically 3-5 m thick. In many cases paleosols, 1-2 m thick, are developed between the flows. Their thickness and extent indicate that the volcanic activity was of an pulsating nature. The basaltic flows are usually horizontal to subhorizontal; only at the margins of the Dead Sea Rift, where the basalt was down faulted, flows are found to be tilted.

The lower flows of the Cover Basalt covered a pre-existing relief filling the erosional surface and thus they unconformably overly older formations (of Cretaceous-Neogene time). In many cases, a paleosol separates the basalts from the underlying formations. In the Lower Galilee and the southern Golan it overlies mainly the Gesher Formation (Schulman, 1959), the Hordos Formation (Bentor, 1946) and locally also Eocene strata (Fig. 3). West of the Sea of Galilee and of the Jordan Valley it covers and interfingers with a pyroclastic-basaltic lens called the Fejjas Tuff which in turn also interfingers with the Gesher Formation (Schulman, 1962; Shaliv, 1991). In the Upper Galilee (Golani Junction) it covers mainly Cretaceous strata while in the Korazim Block it covers Cretaceous to Neogene strata (e.g. Rosh Pinna 1 well).

The upper surface of the Cover Basalt is usually erosional or is covered by young soil. In the center of the Golan, in the Korazim Block, and in the subsurface of the Hula and Jordan valleys, it is covered by younger basalts and/or younger sediments.

LITHOSTRATIGRAPHIC DEFINITION OF THE COVER BASALT

Mor (1973, 1986) mapped the volcanics in the Golan Heights, among them the Cover Basalt, and evaluated criteria for the stratigraphic subdivision of the succession. Mor concluded that no simple lithostratigraphic, geochemical and paleomagnetic criteria could be suggested, and the only applicable criteria were shown to be volcano-morphologic ones. Weinstein et al. (1994) confirmed, in the case of Pleistocene units, the division suggested by Mor, using advanced

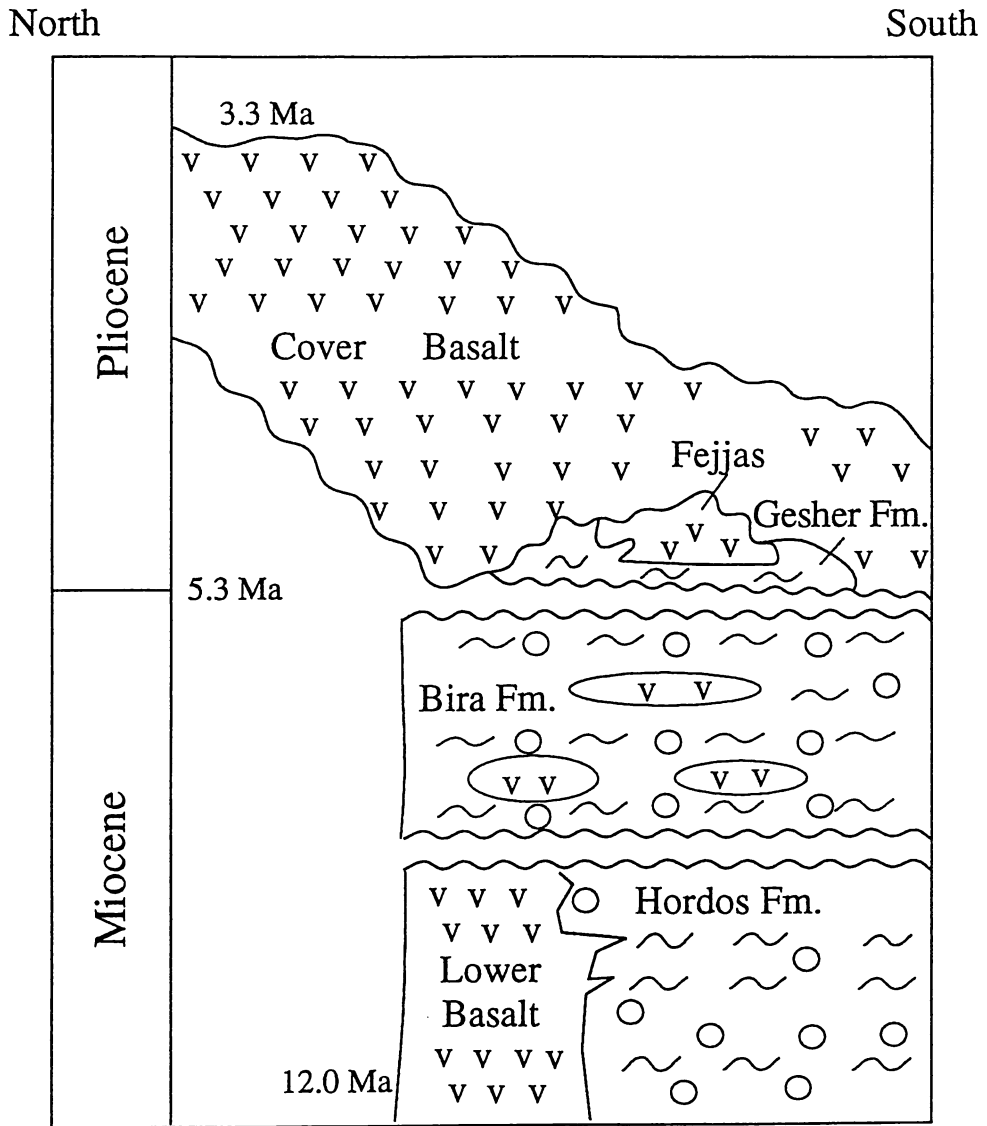


Fig. 3. Schematic stratigraphic section of the Cover Basalt and related units.

geochemical and mineralogical criteria. It is probable that this reasoning and such criteria will be also applicable to older units.

The definition of the Cover Basalt, as originally proposed by Schulman (1962), relies on classical stratigraphic criteria: a basalt outcrop (sequence) is considered to belong to the Cover Basalt when a basalt overlies Late Miocene sedimentary units (e.g. Bira and Gesher formations) or is overlain by younger sedimentary units (in wells like Zemah 1 and Notera 3). Problems arose when: (a) the underlying unit is not exposed or turns out to be of pre-Miocene age; (b) the basalt directly overlies older basalts (Intermediate or Lower Basalt); (c) basalt constitutes the top of the section or, (d) when the Cover Basalt is covered by younger basalts (non-Cover Basalt) of Upper Pliocene and Pleistocene age (see Heimann, 1990).

This obstacle is especially serious when trying to map the Cover Basalt, as in many outcrops the field definition of the Cover Basalt encounters the above mentioned problems. Therefore, in addition to field relationships, it is suggested to apply geochronology to correlate a specific basalt outcrop to a known stratigraphic unit. It should be noted that this approach should be used carefully: correlation is allowed only for the dated site and its immediate vicinity, taking into account that in a volcanic terrain stratigraphic lateral extension is often limited. This is especially critical when dealing with basalts in northern Israel which have similar field appearance, similar petrographic features, and a similar major element chemistry.

PREVIOUS DATING

The age of the Cover Basalt was discussed by many investigators : Blake (1928) defined its age as Middle Pliocene; Picard (1943 and earlier) suggested a Lower-Middle Pleistocene age, while Blanckenhorn (1912), Bentor (1946) and Picard (1952) claimed an Upper Pliocene age. Schulman (1959, 1962) attributed an Upper Pliocene - Lower Pleistocene age to the Cover Basalt - an option which Michelson (1972) and Horowitz (1973) also agreed with. These ages were based on stratigraphic, structural, paleoclimatic and other general geologic considerations. Siedner and Horowitz (1974) published the first two K-Ar ages of 1.7-2.0 Ma for this unit (the samples were from Kokhav HaYarden and the vicinity of Tiberias).

Mor and Steinitz (1982) and Mor (1986) presented K-Ar ages from five typical sites of the Cover Basalt in the Lower Galilee and from two sites in the southern Golan Heights. According to their results the age of the formation spans from 3.9 Ma at the base (Nahal Yissakhar) to 3.0 Ma at the top (Poriya I'llit). Since these results were published, the measurement precision of young basalt age in the geochronological laboratory of the Geological Survey has improved. An updated version of results of those published by Mor and Steinitz (1982) and by Mor (1986), and new data (Heimann, 1990; Shaliv, 1991) were compiled and presented by Mor et al. (1990) - suggesting that the Cover Basalt phase took place in the period of 5.3-3.3 Ma.

METHODS

The basalts were dated by the K-Ar and $^{40}\text{Ar}/^{39}\text{Ar}$ techniques. In the next paragraphs a short description of the techniques as used are given. For additional details see Mor (1986), Heimann (1990), Heimann et al. (1992) and Heimann and Ron (1993).

K-Ar

Several rock samples (2 to 4) were collected from each site. Each sample (~1 kg) was crushed and sieved (70-90 mesh) and washed with water, alcohol and acetone. Final cleaning of the samples was carried out by magnetic separation. Recently we have also used 0.5 N HCl for leaching the samples for 1h. K was measured by atomic absorption and ^{40}Ar by isotope dilution. The K concentration of each sample was measured at least twice and usually four times and the uncertainty is less than 2%. The Ar of each sample was measured once or twice. Prior to extraction, samples (wrapped in low Ar blank aluminum foil) were baked for 8-12 hours at $\sim 180^\circ\text{C}$ and the system attained a vacuum in the range of 1×10^{-9} mbar. Ar extraction was conducted in a molybdenum crucible by melting through induction heating in a metal line.

Ar was analyzed on a MM-1200 mass spectrometer. Net peak heights of at least five runs were extrapolated linearly to inlet time. Peak and background integration times were 15 s. The sensitivity of the mass spectrometer, equipped with a Faraday cup, is 2.6×10^{-4} Amp/Torr. Periodic extraction line blanks show constant values (5×10^{-9} cc STP of ^{40}Ar) which generally has an atmospheric $^{40}\text{Ar}/^{36}\text{Ar}$. A typical sample has about 1×10^{-6} cc STP of ^{40}Ar (4.46×10^{-11} moles).

The mean value of the ratio $^{40}\text{Ar}/^{36}\text{Ar}$ of atmospheric Ar was routinely measured with a precision exceeding 0.5% on the ratio. The calibration of the ^{38}Ar spike is done using LP-6 standard biotite and the uncertainty is $\leq 0.5\%$ (Heimann and Steinitz, 1988). The constants used are according to IUGS (Steiger and Jäger, 1977).

Uncertainties on a single measurement were calculated using the Gauss method as described by Heimann (1990). Mean uncertainties of multiple samples from a single site were derived using a formulation taking into account the uncertainty of each individual determination and the dispersion of ages of multiple samples of each site. This formulation results in a larger uncertainty than would be implied by single standard deviation on the ages. This formulation probably represents the actual uncertainties better than the conservative estimations (for more details see Heimann, 1990).

$^{40}\text{Ar}/^{39}\text{Ar}$

Aliquots of samples (weighed and wrapped in a low Ar blank Al foil) are packed together with monitors in a quartz tube. The samples were irradiated in the D-17 position at the IRR-1 reactor at the Soreq Nuclear Research Center, Israel. Irradiation parameters ("J" values) were determined using the interlaboratory monitor HD-B1 with an age of 24.7 Ma (Führmann et al., 1986). A systematic uncertainty of $\pm 1\%$ is assigned to the J value in order to allow for uncertainty in the monitor age (for more details see Heimann et al., 1992). Ar was analyzed as described above.

Measurements which were previously published by Mor (1986), Heimann (1990), Shaliv (1991) and some additional measurements performed after 1991, were all recalculated on a similar basis. The difference between the previously published individual results and those re-published here are minor.

RESULTS

K-Ar

In the present study we have compiled and re-evaluated data from measurements conducted on Cover Basalt samples at the GSI geochronological laboratory since 1982. The sites include

basaltic flows, cinder cones, dykes and boreholes. It should be borne in mind that sampling of the basalt sequence was governed by local geologic considerations (e.g. aims of projects, outcrops accessibility etc.). Therefore, the sampling is biased in terms of an overall stratigraphic evaluation of the Cover Basalt. Still the base and top of the sequence were sampled and measured in several sites including N. Yissakhar and Hirbet Gvul which are the "type section" localities as defined by Schulman (1962) (see Fig. 4).

Compilation of the results are presented in Tables 1 & 2. Table 3 presents the mean age of sites which are included as a part of the Cover Basalt unit (by age and location - to be discussed later) while Table 4 show the mean age of sites from adjacent areas which are geochronologically synchronous with the Cover Basalt.

$^{40}\text{Ar}/^{39}\text{Ar}$

In recent years Cover Basalt samples were analyzed using the $^{40}\text{Ar}/^{39}\text{Ar}$ technique. Several samples were from boreholes - Notera 3, Ammi'ad 1, Kinneret 4 and Rosh Pinna 1 (Heimann, 1990). Others were from the southern Golan (Ron et al., 1992) and two from the Jordan Valley south of the Sea of Galilee (Heimann, unpublished results). The results are summarized in Table 5. The sampling, in these cases, was not oriented to represent the stratigraphic span of the Cover Basalt sequence.

In order to better define the age of the Cover Basalt sequence we have chosen 11 additional sites, previously dated by the K-Ar technique, to be measured using the $^{40}\text{Ar}/^{39}\text{Ar}$ step-wise heating procedure. The sites selected, were from different areas and represent the base and top of the sequence. The analytical results are given in Table 6, the individual spectra are shown in Fig. 5 and summary of the results is presented in Table 7.

As mentioned, samples were collected at the base, top or within the section. Only sites which clearly cover the underlying sedimentary units were identified as basal sites. Sites which are located close to the base of the sequence were not included and rather identified as "within" the sequence together with other sites. Therefore, occurrence of relatively old ages within the sequence should not surprise. The same consideration applies to the top of the section. In eroded areas samples collected at the surface could be originally located within the sequence and therefore can have relatively old ages.

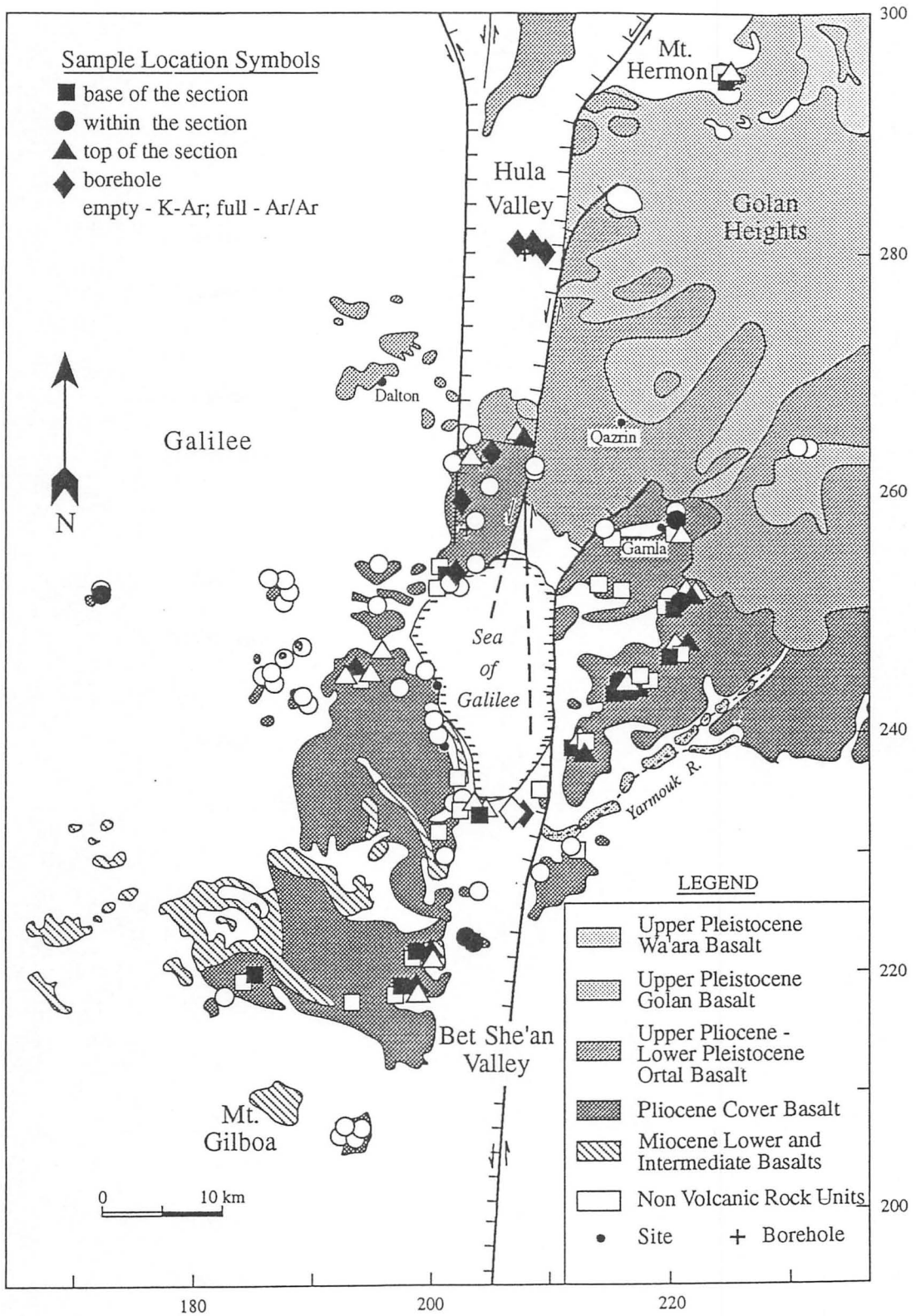


Fig. 4. Dated Cover Basalt sites in Israel.

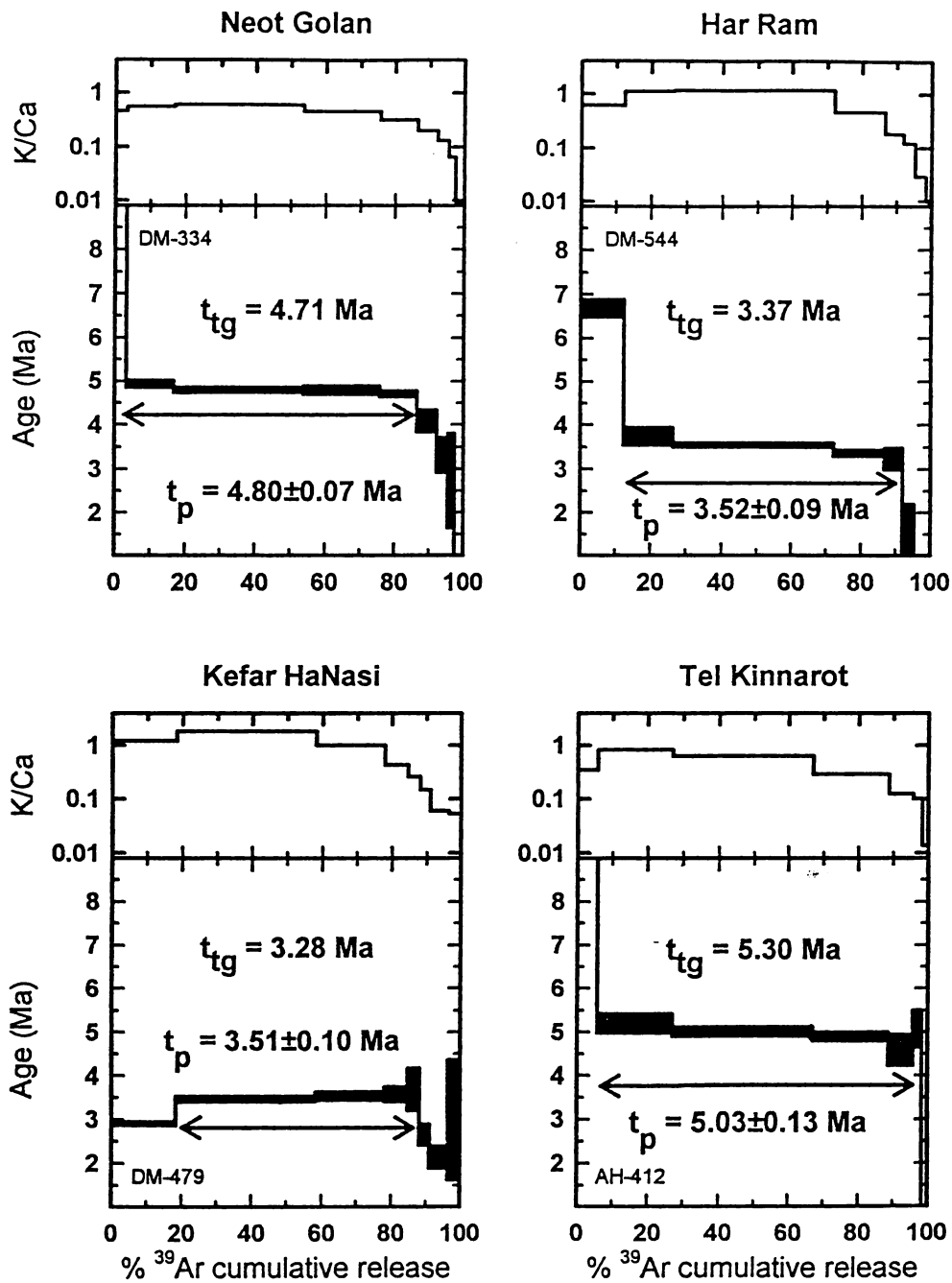


Fig. 5a. $^{40}\text{Ar}/^{39}\text{Ar}$ age spectra for basalts belonging to the Cover Basalt Formation from the Korazim Block and the Golan Heights. The site name and the sample identification (bottom left) are given for reference. t_{tg} = the total-gas age obtained by integration of all gas fractions; t_p = plateau age with 1σ analytical uncertainty.

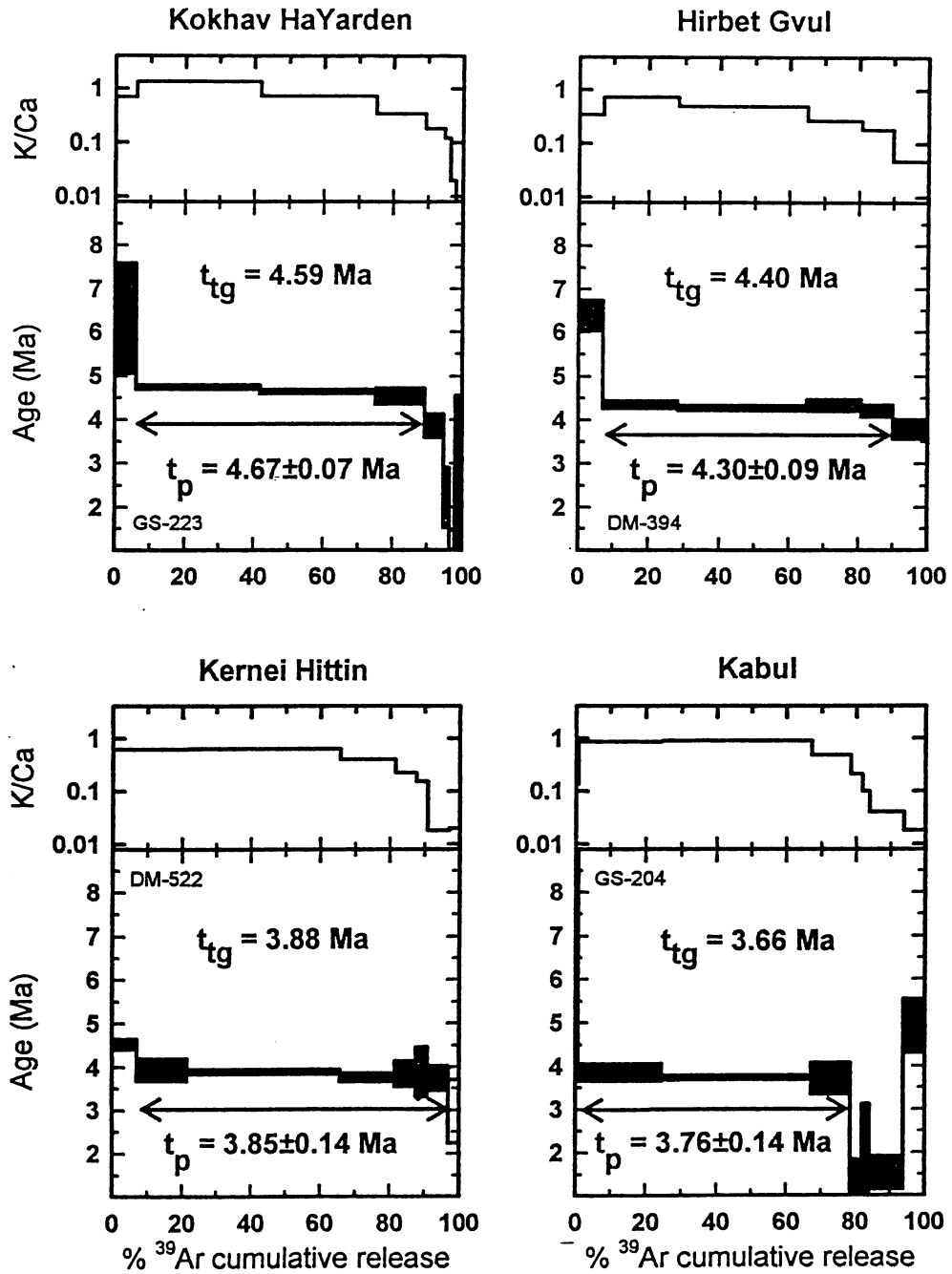


Fig. 5b. ⁴⁰Ar/³⁹Ar age spectra for basalts belonging to the Cover Basalt Formation from the top of the section in the Galilee.

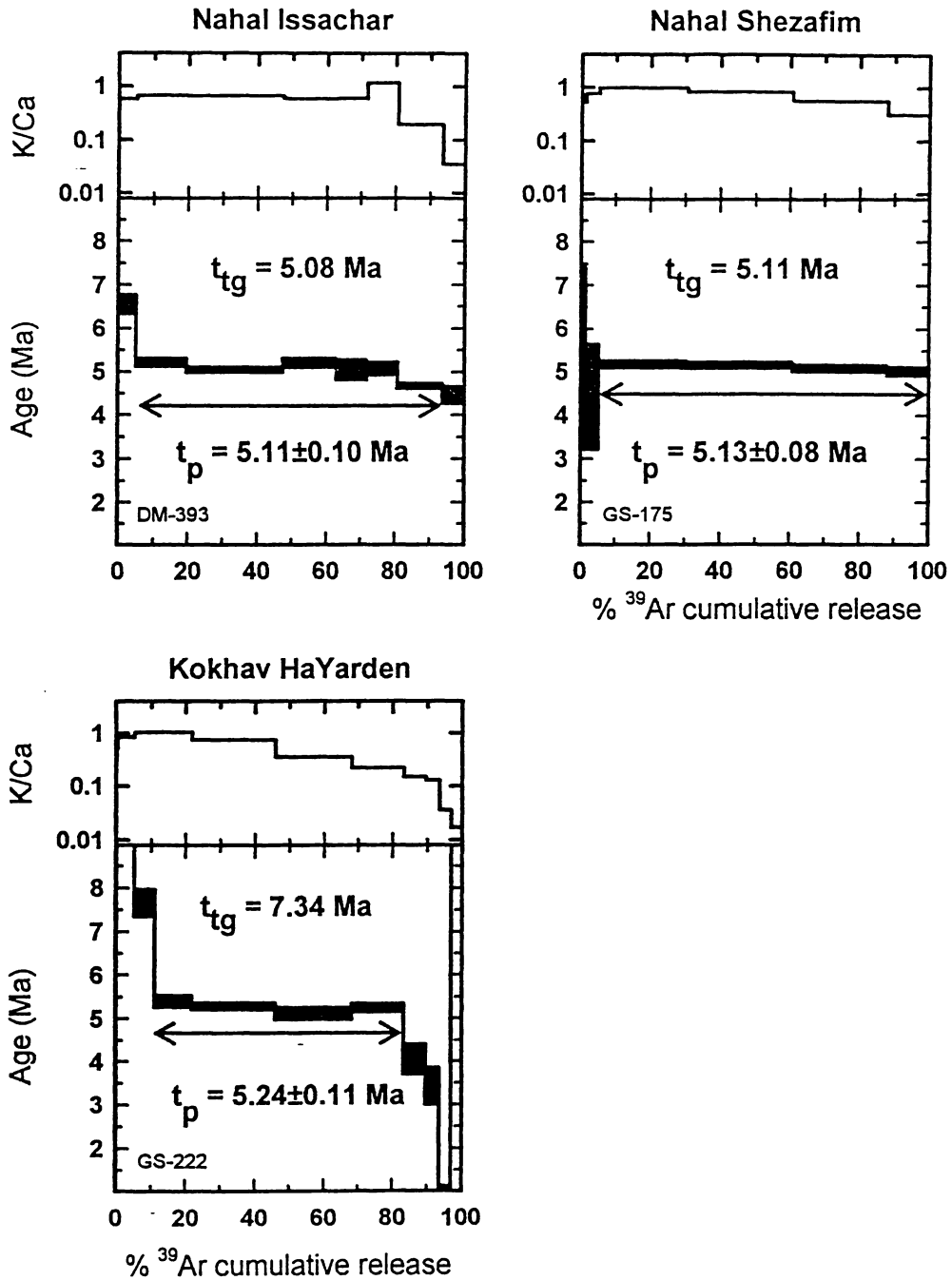


Fig. 5c. $^{40}\text{Ar}/^{39}\text{Ar}$ age spectra for basalts belonging to the Cover Basalt Formation from the base of the section in the Galilee.

The results for the different parts of the section are summarized in Tables 3 and 7. The K-Ar results (Table 3) for the different sites are stratigraphically grouped (top, base and within the section). The sites located to the east and west of the Dead Sea Transform are separated. The $^{40}\text{Ar}/^{39}\text{Ar}$ results (old and new) are presented in Tables 5 and 7. The $^{40}\text{Ar}/^{39}\text{Ar}$ age determinations usually agree (within the uncertainties) with the K-Ar results conducted on the same samples (Table 7).

CONCLUSIONS

The Cover Basalt is the most significant Tertiary volcanic phase according to its volume and distribution in northern Israel, in southern Syria and in northern Jordan. None of the earlier and later volcanic activity during the last 18 m.y. (including the Lower Basalt) was of such intensity. The Cover Basalt volcanism erupted mainly from volcanic lava cones and rarely from cinder cones and fissure eruptions (dykes).

The Cover Basalt unit appears to be a highly diachronic unit. The ages obtained for sites at the base of the sequence are 5.5-4.0 Ma (Table 3,7), showing significant differences which are beyond the analytical uncertainty. The same is with the sites at the top of the section which were dated to 4.7-3.3 Ma. The dating indicates that the unit started and ended to erupt in different areas at different time (Fig. 3). This spread probably reflects the fact that the basalt covered an erosional unconformity and evidently the early basalt flows first filled the topographic lows. One exceptional site, which should be mentioned, is Har Ram in the northern Golan Heights: a basaltic unit, directly overlying Cretaceous rocks (and therefore should be considered as being the "base" of the basalts), was dated to 3.5 Ma. This example clearly shows that the age of the base of the Cover Basalt may vary geographically. Similar considerations apply to the uppermost part of the exposed section: the original top may be eroded and the sampling might not represent the youngest basalt erupted at a specific location.

Extreme (= "end member") age values, which represent the age of the sequence considered by the authors as "Cover Basalt", are therefore 5.5-4.0 Ma for the base and 4.7-3.3 Ma for the top (Table 8). **The overall age of the Cover Basalt unit is therefore suggested here to span the interval from 5.5 to 3.3 Ma.**

The updated ages for the classical type section in the Lower Galilee (Schulman, 1962) are 4.6 (base) and 4.2 Ma (top). As far as we could determine, and apparently from the above mentioned point of view, there is no any preferred section in which the whole volcanic sequence of the Cover Basalt is represented.

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Table 1:

Location and K-Ar analytical data of Cover Basalt samples. Samples are organized in geographical order from west to east. All samples are from flows, except when stated otherwise.

Location	Sample No.	Measurement No.	%K	% ⁴⁰ Ar Rad.(*)	⁴⁰ Ar* cc/gr X 10 ⁷	Age (Ma)	
Kabul	GS	204	3117	0.9400	14.99	1.302	3.56±0.10
Kabul	GS	205	3116	0.8900	14.33	1.461	4.22±0.12
N. Nurit	GY	2a	1817	0.5300	13.05	1.071	5.19±0.15
N. Nurit	GY	2b	1805	0.7550	23.98	1.402	4.77±0.11
N. Nurit	GY	2c	1807	0.5250	18.12	1.080	5.29±0.13
N. Shezafim	GS	175	2735	0.7050	49.74	1.498	5.46±0.11
N. Shezafim	GS	176	2817	0.7350	41.47	1.476	5.16±0.11
Dike cutting Tura'an	UK	4116	1838	1.0900	53.46	1.768	4.17±0.09
Dike cutting Tura'an	UK	4117	1839	2.0850	59.65	3.253	4.01±0.08
Tur'an	DM	524	1777	0.9050	16.36	1.364	3.87±0.10
Tur'an	DM	525	2542	0.8550	32.40	1.454	4.37±0.09
Tur'an	DM	526	2543	0.9750	38.78	1.688	4.45±0.09
Mitzpe Netufa Dike	UK	4115	1837	1.8700	68.76	2.679	3.68±0.08
West of Zalmon	UK	4119	1842	0.8000	23.98	1.281	4.12±0.09
Deir Hana	AH	1041	6198	1.1000	45.07	1.773	4.14±0.11
Biqaat Zalmon-Deir Hanna Rd.	UK	4118	1841	1.0750	17.43	1.707	4.08±0.10
Deir Hanna	AH	571	2563	0.5940	34.15	1.055	4.57±0.10
Deir Hanna	AH	571	2488	0.5940	41.56	1.030	4.46±0.09
Deir Hanna	AH	572	2553	0.6450	22.09	1.083	4.31±0.10
Netofa Junction	DM	473	2533	0.4800	12.54	0.851	4.55±0.13
Netofa Junction	DM	474	2534	0.4650	27.26	0.884	4.88±0.11
Golani junction (dike)	UK	4114	1836	0.9850	46.56	1.702	4.44±0.09
Golani junction	DM	503	2536	0.9650	49.27	1.684	4.49±0.09
Golani junction	DM	504	1885	0.9270	34.73	1.465	4.06±0.09
Golani junction	DM	505	1775	0.9800	20.34	1.507	3.95±0.09
H. Amudim	DM	500	2535	1.0000	33.29	1.722	4.43±0.10
H. Amudim	DM	501	1676	0.9900	21.82	1.596	4.14±0.10
H. Amudim	DM	502	1688	1.3000	45.51	2.210	4.37±0.09
N. Avinadav north (dike)	GR	7	1790	0.8950	37.48	1.613	4.63±0.10
N. Avinadav south	GR	5a	1794	0.9550	29.53	1.496	4.03±0.09
N. Avinadav south	GR	5b	1795	1.0175	44.72	2.189	5.53±0.12
N. Avinadav south	GR	5c	1797	1.0200	39.03	1.957	4.93±0.10
N. Avinadav south	GR	6a	1808	0.9950	33.74	1.756	4.54±0.10
N. Avinadav south	GR	6b	1818	0.9800	28.88	1.903	4.99±0.11
N. Avinadav south	GR	6c	1819	0.9850	29.85	1.836	4.79±0.10
Giveat Zevaim	DM	531	2337	0.7200	48.32	1.464	5.22±0.11
Qarne Hittim N. (top)	DM	521	1892	1.0000	32.69	1.543	3.96±0.09
Qarne Hittim N. (top)	DM	522	1778	0.8850	14.16	1.365	3.96±0.11
Qarne Hittim N. (top)	DM	523	2548	0.6150	4.11	1.017	4.25±0.31
Qarne Hittim S. (base)	DM	518	1776	0.8740	19.15	1.453	4.27±0.10
Qarne Hittim S. (base)	DM	519	1891	0.8650	31.19	1.419	4.22±0.09
Qarne Hittim S. (base)	DM	520	2539	0.8750	37.39	1.525	4.48±0.10

Location	Sample No.	Measurement No.	%K	% ⁴⁰ Ar Rad.(*)	⁴⁰ Ar* cc/gr X 10 ⁷	Age (Ma)	
N. Avinadav north	GR	8a	1791	0.7200	23.01	1.321	4.71±0.11
N. Avinadav north	GR	8b	1792	0.8000	20.63	1.335	4.29±0.10
N. Avinadav north	GR	8c	1793	0.8850	33.87	1.570	4.56±0.10
Achuzat Naftali	DM	515	1585	0.7960	49.13	1.219	3.94±0.08
Achuzat Naftali	DM	516	1879	0.6800	30.19	1.024	3.87±0.08
Har Ravid	AH	381	1787	0.5750	32.95	0.995	4.45±0.10
Har Ravid	AH	382	1788	0.6080	31.79	0.966	4.08±0.09
Kallanit	AH	561	2448	0.7300	15.94	1.385	4.88±0.13
Kallanit	AH	562	2487	0.6960	16.90	1.225	4.52±0.12
Kallanit	AH	563	2575	0.7100	17.71	1.382	5.00±0.12
Arbel	DM	512	2560	0.6520	18.89	1.050	4.14±0.10
Arbel	DM	513	1689	0.6740	36.23	0.999	3.81±0.08
Arbel	DM	514	2537	0.7250	37.95	1.111	3.94±0.08
Mizpa (Poriya junction)	AH	581	2573	1.0200	30.46	1.965	4.95±0.11
Mizpa (Poriya junction)	AH	582	2554	0.9540	43.88	1.739	4.68±0.10
Mizpa (Poriya junction)	AH	583	2555	0.5850	44.48	1.100	4.83±0.10
N. Yissakhar,	DM	391	2889	1.0700	42.56	1.960	4.71±0.10
N. Yissakhar	DM	392	2890	1.1700	34.27	2.082	4.57±0.10
H. Gvul	DM	394	1877	0.7600	34.97	1.247	4.22±0.09
Kokhav HaYarden (top)	GS	223	2820	0.7750	28.01	1.279	4.24±0.09
Kokhav HaYarden (top)	GS	224	2824	0.8700	29.76	1.582	4.67±0.10
Kokhav HaYarden (base)	GS	221	2846	0.7500	29.36	1.516	5.19±0.11
Kokhav HaYarden (base)	GS	222	2733	0.8000	35.57	1.624	5.22±0.11
Yavne'el	DM	325	2879	0.8900	44.23	1.618	4.67±0.10
Yavne'el	DM	326	2880	0.8300	50.93	1.572	4.87±0.10
Yavne'el	DM	327	1876	0.8600	52.21	1.665	4.97±0.10
Yavne'el	DM	327	2881	0.8600	54.83	1.581	4.72±0.10
HaHof HaShaqet	AH	591	2493	0.6340	37.43	1.214	4.92±0.10
HaHof HaShaqet	AH	592	2494	0.5150	36.88	0.969	4.83±0.10
HaHof HaShaqet	AH	593	2586	0.5050	34.39	0.975	4.96±0.11
Kh. E-Dir	GS	169	2815	3.9300	50.35	6.797	4.44±0.09
Kh. E-Dir	GS	34	2334	1.2950	32.13	2.592	5.14±0.11
Tel Kinnarot	AH	411	2241	0.5950	29.69	1.213	5.24±0.11
Tel Kinnarot	AH	412	2242	0.7000	49.38	1.444	5.30±0.11
Tel Kinnarot	AH	413	2243	0.6770	38.16	1.266	4.81±0.10
Tabkha well 16m	U4S	16	2922	0.6600	6.40	1.106	4.31±0.21
Tabkha well 18m	U4S	18	2923	0.6100	17.76	1.177	4.96±0.12
Tabkha well 5m	U4S	5	2921	0.6800	22.83	1.144	4.32±0.10
N. Yavne'el	GS	30	2317	0.9000	25.06	1.573	4.49±0.10
N. Yavne'el	GS	31	2318	0.9700	36.87	1.751	4.64±0.10
N. Yavne'el - Fejjas Tuff	GS	26	1815	0.5500	13.48	1.174	5.48±0.15
N. Yavne'el - Fejjas Tuff	GS	27	1816	0.6900	19.53	1.356	5.05±0.12
N. Yavne'el - Fejjas Tuff	GS	28	1813	0.7150	15.21	1.359	4.88±0.13
N. Yavne'el - Fejjas Tuff	GS	33	1854	0.5950	8.20	1.118	4.83±0.19
Filon	DM	494	2076	1.5120	62.20	2.573	4.37±0.09
Filon	DM	495	1912	1.4100	53.71	2.350	4.28±0.09
Filon	DM	496	2026	0.9170	55.85	1.588	4.45±0.09
Filon	DM	496	2544	0.9170	34.05	1.631	4.57±0.10

Location	Sample No.	Measurement No.	%K	^{40}Ar Rad.(*)	$^{40}\text{Ar}^*$ cc/gr X 10^7	Age (Ma)	
W. Qasab dike	GS	8	2371	1.3500	41.37	2.196	4.18±0.09
W. Qasab dike	GS	9	2522	1.4450	44.86	2.561	4.55±0.10
W. Qasab dike	UK	20	1835	1.2000	24.99	1.967	4.21±0.10
Mizpe Kinnarot	DM	328	2882	0.9800	26.27	1.757	4.61±0.10
Mizpe Kinnarot	DM	329	2883	0.9600	27.85	1.742	4.66±0.10
Mizpe Kinnarot	DM	330	2884	1.1000	37.13	1.944	4.54±0.10
Poriyya	GS	78	2531	1.3850	33.69	2.380	4.42±0.10
Poriyya	GS	76	2366	1.5550	33.49	2.997	4.95±0.11
Ubeidiya	AH	741	2964	0.7100	15.74	1.226	4.44±0.12
Ubeidiya	AH	743	910001	0.7300	18.83	1.279	4.51±0.16
Ubeidiya	AH	743	2988	0.7250	27.89	1.300	4.61±0.10
NW of Naharaim	DB	56	910006	0.8400	17.55	1.553	4.81±0.27
NW of Naharaim	DB	56	910005	0.7400	13.35	1.400	4.70±0.29
Nw of Naharaim	DB	56	910007	0.8090	19.43	1.495	4.70±0.24
Ubeidiya North	AH	802	3074	0.6830	14.16	1.188	4.47±0.12
Tel Nes	DM	491	2079	0.8620	45.23	1.439	4.29±0.09
Tel Nes	DM	492	2065	0.8530	42.19	1.352	4.07±0.09
Tel Ya'af	AH	541	2466	0.6250	7.07	1.062	4.37±0.19
Tel Ya'af	AH	542	2754	0.6000	21.42	1.009	4.32±0.10
Tel Ya'af	AH	543	3122	0.5850	11.08	1.069	4.70±0.15
Korazim	DM	497	1675	0.7600	17.75	1.154	3.90±0.10
Korazim	DM	498	1686	0.8030	45.02	1.239	3.96±0.08
Korazim	DM	499	1687	0.7360	45.16	1.080	3.77±0.08
Kefar Nahum	AH	601	2495	0.5650	19.38	1.048	4.76±0.12
Kefar Nahum	AH	602	2496	0.6070	34.79	1.200	5.08±0.11
Kefar Nahum	AH	603	2587	0.8070	35.36	1.502	4.78±0.10
Kefar Nahum	AH	603	2828	0.8070	34.88	1.433	4.56±0.10
Mahane Yiftah	AH	551	2456	0.7120	21.66	1.257	4.54±0.11
Mahane Yiftah	AH	552	2853	0.6400	10.99	1.201	4.82±0.15
Zemah #1 well	ZMCH	3805	1695	2.9165	21.75	4.434	3.91±0.09
Zemah #1 well	ZMCH	3805	1694	2.2468	27.78	3.806	4.35±0.10
Zemah #1 well	ZMCH	3805	1167	1.5688	8.87	2.373	3.89±0.14
Zemah #1 well	ZMCH	3805	938	1.6491	18.38	2.667	4.16±0.10
Zemah #1 well	ZMCH	3805	1134	2.2468	34.73	3.661	4.19±0.09
Zemah #1 well	ZMCH	3805	1133	2.9165	35.90	4.448	3.92±0.08
Zemah #1 well	ZMCH	3805	1691	1.5688	7.00	2.337	3.83±0.17
Zemah #1 well	ZMCH	3805	1135	1.5688	14.96	2.827	4.63±0.12
Zemah #1 well	ZMCH	3805	940	2.9165	45.73	6.212	5.47±0.11
Zemah #1 well	ZMCH	3805	939	0.8428	14.52	1.596	4.87±0.13
Kefar HaNasi	DM	479	1584	1.4320	53.10	1.821	3.27±0.07
Kefar HaNasi	DM	479	2025	1.4320	55.00	1.846	3.31±0.07
Kefar HaNasi	DM	480	1684	0.5170	14.41	0.797	3.96±0.11
Kefar HaNasi	DM	481	1685	0.5380	17.92	0.756	3.61±0.09
Einot Shaqed South	AH	401	1932	0.6830	10.02	0.981	3.69±0.13
Einot Shaqed South	AH	402	2067	0.6800	20.01	0.877	3.31±0.08
Einot Shaqed South	AH	403	2074	0.7600	18.23	0.985	3.33±0.08
Einot Shaqed South	AH	403	2840	0.7600	20.97	1.195	4.04±0.10

Location	Sample No.	Measurement No.	%K	% ⁴⁰ Ar Rad.(*)	⁴⁰ Ar* cc/gr X 10 ⁷	Age (Ma)
Einot Shaqed North	AH 391	1931	0.5970	6.31	1.034	4.45±0.22
Einot Shaqed North	AH 391	2837	0.5970	12.70	1.005	4.32±0.13
Einot Shaqed North	AH 393	2073	0.8870	31.13	1.478	4.28±0.09
Tel Katzir (flow in Gesher Fm.)	DM 509	1678	0.3420	4.39	0.694	5.21±0.36
North Shune	GSDM 10	2672	0.5400	12.85	1.118	5.32±0.15
North Shune	GSDM 11	2678	0.6600	9.90	1.313	5.11±0.17
North Shune (base)	GSDM 12	2697	0.5350	11.67	1.134	5.45±0.17
Mevo Hama (base)	AH 963	4332	0.4300	20.81	0.751	4.49±0.11
Mevo Hama (top)	DM 305	1869	0.7500	35.28	1.307	4.48±0.10
Mevo Hama (top)	DM 307	1863	0.7900	30.32	1.357	4.41±0.10
N. Kanaf - Fejjas Tuff	DM 338	2888	0.7100	35.66	1.334	4.83±0.10
N. Kanaf - Fejjas Tuff	DM 339	2654	0.7720	32.71	1.562	5.20±0.11
Golan north of Sheich Ali F.	P 88	4049	0.8800	33.94	1.392	4.07±0.09
Golan north of Sheich Ali F.	P 89	4050	0.8300	39.47	1.489	4.61±0.10
Ma'ale Gamla	AH 711	2702	0.5190	29.29	0.981	4.86±0.11
Ma'ale Gamla	AH 712	2750	0.6300	42.29	1.196	4.88±0.10
Ma'ale Gamla	AH 713	2751	0.6370	50.08	1.163	4.69±0.10
Neot Golan	DM 334	2885	0.7700	44.38	1.480	4.94±0.10
Neot Golan	DM 335	2950	0.8250	19.01	1.560	4.86±0.12
Neot Golan	DM 335	2886	0.7900	40.12	1.494	4.86±0.10
Neot Golan	DM 336	2887	0.7400	40.07	1.457	5.06±0.11
N. Kanaf - Fejjas Tuff	GS 153	3103	0.7250	8.65	1.448	5.13±0.19
N. Kanaf - Fejjas Tuff	GS 154	2591	0.6700	9.59	1.389	5.33±0.19
Afik (top)	AH 952	5098	0.7200	4.83	1.222	4.36±0.28
Afik (base)	AH 942	5100	0.4350	21.12	0.822	4.86±0.15
N. Sameq (base)	AH 911	4329	0.7350	4.11	1.516	5.30±0.38
N. Sameq (base)	AH 913	4338	0.7550	22.54	1.612	5.48±0.13
N. Sameq Middle flow	AH 921	5044	0.6900	29.72	1.121	4.17±0.14
N. Sameq Middle flow	AH 922	5097	0.7000	31.32	1.147	4.21±0.16
N. El-Al (top)	AH 891	5032	0.4350	7.20	0.738	4.36±0.38
N. El-Al (top)	AH 892	4339	0.4650	11.92	0.838	4.63±0.14
N. El-Al (top)	AH 893	5089	0.3750	18.65	0.605	4.15±0.14
N. El Al (base)	AH 881	910002	0.8300	18.95	1.708	5.23±0.20
N. El-Al (base)	AH 883	4340	0.4750	24.66	0.892	4.83±0.11
N. Sameq (top)	AH 931	5112	0.5600	9.06	0.941	4.32±0.17
N. Sameq (top)	AH 933	5108	0.6400	4.22	1.020	4.10±0.33
Giv'at Natur	DM 443	2955	0.8100	53.00	1.362	4.32±0.09
Giv'at Natur	DM 444	2987	0.7720	53.37	1.285	4.28±0.09
Gamla (base)	DM 421	2952	1.1870	60.66	2.049	4.43±0.09
Gamla (base)	DM 422	2984	0.9210	33.85	1.553	4.33±0.09
Gamla (top)	DM 424	2953	0.8980	33.27	1.365	3.91±0.08
Gamla (top)	DM 425	2985	0.9090	38.77	1.402	3.96±0.08
Giv'at Bezeq	AH 902	5094	0.8650	23.93	1.474	4.38±0.10
Giv'at Bezeq	AH 903	5031	0.8200	6.30	1.683	5.27±0.29
Giv'at Bezeq	AH 903	3859	0.8200	12.91	1.593	4.99±0.14
Giv'at Bezeq	AH 903	4345	0.8200	13.50	1.655	5.18±0.15
Giv'at Bezeq	DM 427	2954	0.6510	19.20	1.106	4.36±0.11

Location	Sample No.	Measurement No.	%K	% ⁴⁰ Ar Rad.(*)	⁴⁰ Ar* cc/gr X 10 ⁷	Age (Ma)
Har Ram (base)	DM 542	1893	0.8500	38.97	1.160	3.51±0.07
Har Ram (base)	DM 543	2301	0.9000	32.96	1.343	3.83±0.08
Har Ram (base)	DM 544	2302	0.9500	40.12	1.561	4.22±0.09
Har Ram (top)	DM 370	2303	1.1350	47.28	1.641	3.72±0.08
Har Ram (top)	DM 371	2304	0.9550	41.73	1.268	3.41±0.07
Har Ram (top)	DM 372	2305	1.0540	38.65	1.509	3.68±0.08
Har Peres (west)	DM 528	3114	0.6750	9.09	1.321	5.03±0.18
Har Peres (top)	DM 529	1753	1.1300	18.79	2.428	5.52±0.13

Table 2:

Location and K-Ar analytical data of basalts having a "Cover Basalt" age and which are located in other areas. Samples are organized in geographical order from west to east. All samples are from flows, except when stated otherwise.

Location*	Sample No.	Measurement No.	%K	⁴⁰ Ar Rad.(*)	⁴⁰ Ar* cc/gr X 10 ⁷	Age (Ma)	
Bat Yam #1 well	H	135	1983	0.7300	28.67	1.254	4.41±0.10
National Park #1 well	H	137	1984	0.5200	14.93	1.030	5.09±0.14
National Park #1 well	H	140	1995	0.5200	16.83	1.121	5.54±0.14
National Park #1 well	H	142	1989	0.5700	17.97	1.154	5.20±0.13
National Park #1 well	H	144	1990	0.6000	19.32	1.282	5.49±0.13
Shukba dike	BB	1200	1120	0.9754	21.96	1.629	4.29±0.10
Shukba dike	BB	1200	1827	0.8898	31.83	1.455	4.20±0.09
Shukba dike	BB	1200	1828	1.0073	24.01	1.549	3.95±0.09
Shukba dike	BB	1200	1083	0.8895	10.39	1.706	4.93±0.16
Shukba dike	BB	1200	1122	1.0073	15.72	1.362	3.48±0.09
Shukba dike	BB	1200	1123	0.3866	4.94	0.824	5.47±0.33
Shukba dike	BB	1200	1829	0.9754	37.50	1.626	4.28±0.09
Shukba dike	BB	1202	1125	1.6129	37.43	3.124	4.98±0.11
Shukba dike	BB	1202	1832	1.5978	67.07	2.497	4.01±0.08
Shukba dike	BB	1202	1830	1.5249	65.39	2.368	3.99±0.08
Shukba dike	BB	1202	1156	1.1322	29.85	2.335	5.30±0.12
Shukba dike	BT	1031	901248	1.0900	8.23	1.994	4.70±0.54
Sa'adat e Talib - Inter. Basalt	GS	45	1994	1.0700	59.65	2.324	5.58±0.12
Sa'adat e Talib - Inter. Basalt	GS	49	1993	1.1900	36.70	2.535	5.47±0.12
Wadi Dana, Jordan	GSDM	25	3968	0.7500	28.34	1.458	5.00±0.11
East Tel Geharira plateau	GSDM	23	2669	0.7300	16.92	1.271	4.47±0.11
Zimriya	DM	551	3986	1.0150	43.48	1.732	4.39±0.09

* Additional details on the location, including coordinates and well depth are accessible in the geochronologic database of the GSI.

Table 3:

Mean ages of dated Cover Basalt sites. Sites are organized according to their position in the section - base, top or within the sequence, are separated to west and east of the Dead Sea Transform and are organized from west to east within each area.

Location	Coordinate (Israel Grid)	No. of analysis	Age (Ma)
<u>BASE OF SECTION</u>			
<u>West of the Dead Sea Transform</u>			
Giveat Zevaim	19310/21730	1	5.22±0.11
N. Yissakhar	19710/21860	2	4.64±0.12
N. Shezafim	18470/21980	2	5.31±0.23
Kokhav HaYarden	19925/22211	2	5.21±0.08
Yavne'el	20000/23150	4	4.81±0.12
N. Yavne'el	20125/23386	2	4.57±0.13
Mizpe Kinnarot	20175/23585	3	4.60±0.09
Qarne Hittim S.	19345/24415	3	4.32±0.15
Tabkha well 18m	20085/25246	1	4.96±0.12
Tel Kinnarot	20080/25300	3	5.12±0.27
<u>East of the Dead Sea Transform</u>			
North Shune	21150/22980	1	5.45±0.17
Tel Katzir (flow in Geshar)	20840/23500	1	5.21±0.36
Mevo Hama	21140/23800	1	4.49±0.11
Neot Golan	21520/24315	4	4.93±0.11
Afik	21580/24330	1	4.86±0.15
N. El Al	21990/24680	2	4.99±0.34
N. Sameq	21900/25020	2	5.39±0.24
N. Kanaf - Fejjas Tuff	21530/25170	2	5.23±0.20
N. Kanaf - Fejjas Tuff	21350/25215	2	5.02±0.27
Ma'ale Gamla	21450/25600	3	4.81±0.12
Gamla	22090/25645	2	4.38±0.10
Har Ram	22335/29430	3	3.85±0.36
<u>WITHIN THE SECTION</u>			
<u>West of the Dead Sea Transform</u>			
N. Avinadav south	19240/20600	3	4.83±0.76
N. Avinadav south	19280/20605	3	4.77±0.23
N. Avinadav north (dike)	19236/20640	1	4.63±0.10
N. Avinadav north	19358/20674	3	4.52±0.22
N. Nurit	18215/21780	3	5.08±0.29

Location	Coordinate (Israel Grid)	No. of analysis	Age (Ma)
NW of Naharaim	20240/22640	3	4.73±0.17
Kh. E-Dir	20060/22960	2	4.49±0.50
Zemah #1 well	20638/23291	10	4.37±0.54
N. Yavne'el - Fejjas Tuff	20118/23372	1	5.14±0.36
N. Yavne'el - Fejjas Tuff	20144/23388	1	4.83±0.19
Poriyya	20196/23982	2	4.69±0.38
W. Qasab (dike)	20170/24115	3	4.31±0.21
Golani junction (dike)	18840/24220	1	4.44±0.09
Golani junction	18850/24250	3	4.17±0.29
Mizpa (Poriya junction)	19680/24350	3	4.82±0.15
Large dike cutting Tura'an	18580/24450	2	4.09±0.13
Tur'an	18585/24465	3	4.23±0.32
HaHof HaShaquet	20060/24480	3	4.90±0.09
Mitzpe Netufa Dike	18640/24490	1	3.68±0.08
Netofa Junction	18760/24595	2	4.69±0.28
H. Amudim	18870/24690	3	4.31±0.16
Har Ravid	19450/25040	2	4.27±0.27
Kabul	17120/25110	2	3.89±0.47
Deir Hana	18690/25130	1	4.14±0.11
Biqaat Zalmon-Dir Hanna Rd.	18690/25160	1	4.08±0.10
Deir Hanna	18700/25170	3	4.45±0.14
West of Zalmon	18670/25200	1	4.12±0.09
Tabkha well 16m	20085/25246	1	4.31±0.21
Tabkha well 5m	20086/25246	1	4.32±0.10
Kallanit	19490/25380	3	4.80±0.26
Kefar Nahum	20330/25380	4	4.80±0.22
Korazim	20320/25760	3	3.88±0.11
Mahane Yiftah	20430/26030	2	4.68±0.22
Einot Shaqed South	20800/26140	4	3.59±0.35
Einot Shaqed North	20810/26180	3	4.35±0.13
Filon	20140/26230	4	4.42±0.13
Tel Ya'af	20280/26440	3	4.46±0.22
<u>East of the Dead Sea Transform</u>			
North Shune	20855/22790	1	5.32±0.15
North Shune	21110/23005	1	5.11±0.17
N. Sameq Middle flow	21930/25040	2	4.19±0.11
Golan north of Sheikh Ali F.	21400/25680	2	4.34±0.39
Giv'at Bezeq	22150/25770	5	4.84±0.44
Har Peres	23075/26325	1	5.52±0.13
Har Peres (west)	23075/26325	1	5.03±0.18

Location	Coordinate (Israel Grid)	No. of analysis	Age (Ma)
<u>TOP OF SECTION</u>			
<u>West of the Dead Sea Transform</u>			
H. Gvul	19820/21860	1	4.22±0.09
Kokhav HaYarden	19917/22211	2	4.46±0.31
Ubeidiya North	20260/23320	1	4.47±0.12
Ubeidiya	20240/23330	3	4.52±0.11
Achuzat Naftali	19425/24470	2	3.91±0.08
Qarne Hittim N.	19330/24520	3	4.06±0.20
Arbel	19515/24660	3	3.96±0.17
Tel Nes	20270/26270	2	4.18±0.17
Kefar HaNasi	20710/26430	4	3.54±0.32
<u>East of the Dead Sea Transform</u>			
Mevo Hama	21140/23800	2	4.45±0.06
Afik	21570/24320	1	4.36±0.28
N. El-Al	21980/24620	3	4.38±0.28
N. Sameq	22050/25050	2	4.21±0.24
Giv'at Natur	22080/25130	2	4.30±0.07
Gamla	22130/25620	2	3.94±0.07
Har Ram	22400/29470	3	3.60±0.17

Table 4:

Location and mean ages of basalts having a "Cover Basalt" age and which are located in other areas. Samples are organized from south to north.

Location	Coordinate (Israel Grid)	No. of analysis	Age (Ma)
Wadi Dana, Jordan	21000/ 4000	1	5.00±0.11
Eastern Tel Geharira plateau, Jordan	22850/ 7000	1	4.47±0.11
Shukba dike	15430/15520	12	4.52±0.52
Bat Yam #1 well	12539/15782	1	4.41±0.10
National Park #1 well	13399/16200	4	5.54±0.26
Sa'adat e Talib - Intermeiate Basalt	20120/18780	2	5.53±0.12
Zimriya	74975/70125	1	4.39±0.09

Table 5:

Summary of previously dated $^{40}\text{Ar}/^{39}\text{Ar}$ samples from the Cover Basalt. Samples are organized from south to north.

Location	Coordinate (Israel Grid)	Sample No.	Total Gas Age (Ma)	Plateau Age & Error (Ma)	Source
Neve Ur	20280/22200	DB 85	4.65	4.45±0.48	2
Neve Ur	20300/22200	DB 86	4.92	4.53±0.16	2
Ubeidiya (base)	20240/23330	AH 743	5.58	4.98±0.16	2
Mevo Hama (base)	21140/23800	AH 962	4.93	4.88±0.07	1
Mevo Hamm (top)	21140/23800	AH 972	4.46	4.50±0.38	1
Afiq	21570/24320	AH 953	4.93	4.59±0.22	1
Afiq (base)	21580/24330	AH 941	4.99	4.91±0.10	1
Afiq (base)	21580/24330	AH 943	4.89	4.88±0.10	1
Nahal El Al (top)	21980/24620	AH 892	5.11	4.55±0.15	1
Nahal El Al (base)	21990/24680	AH 881	5.00	4.82±0.37	1
Nahal Sameq (base)	21900/25020	AH 912	5.59	5.45±0.08	1
Nahal Sameq Middle Flow	21930/25050	AH 921	4.38	4.37±0.10	1
Nahal Sameq (top)	22050/25050	AH 931	4.68	4.06±0.16	1
Tel Bezek	22150/25750	AH 903	4.89	4.71±0.07	1
<u>Wells</u>					
Zemah 2674 m Gabbro	20638/23291	ZEM 2674/2	3.92	4.05±0.07	3
Kinneret 4 88 m	20182/25326	AH 1101	4.06	3.90±0.06	5
Rosh Pinna 1 195 m (base)	20421/26306	AH 1141	4.56	4.00±0.05	5
Ammi`ad 1 85 m (base)	20200/25900	AH 1112	4.34	4.19±0.06	5
Notera 3 1657-1663 m (top)	20761/28008	N 6 [1-meas.]	3.34±0.16	-----	4
Notera 3 2246-2273 m	20761/28008	N 8-9 [4 meas.]	3.46±0.43	-----	4
Notera3 2321-2427m (base)	20761/28008	N 10-12 [4 meas.]	4.08±0.51	-----	4

Each sample was measured once; samples from Notera #3 well were measured as total fusions [no. of duplicate measurements in brackets].

Sources:

(1) Ron, Heimann and Garfunkel, 1992; (2) Heimann, unpublished data; (3) GSI, unpublished data; (4) Heimann and Steinitz, 1989 (measured as total gas fusion); (5) Heimann, 1990.

Table 6:

⁴⁰Ar/³⁹Ar analytical data and apparent ages for samples from the Cover Basalt Formation

Step No.	⁴⁰ Ar/ ³⁹ Ar ^a	³⁷ Ar/ ³⁹ Ar ^a	³⁶ Ar/ ³⁹ Ar ^a	⁴⁰ Ar*/ ³⁹ Ar ^b	% ³⁹ Ar ^c	% ⁴⁰ Ar* ^d	K/Ca ^e	Apparent Age (Ma) ^f
DM 393 - Nahal Yissakhar (meas. 42/6331; J = 0.00319500; Fig. 3a)								
1	7.17	1.14	0.0206	1.14	5.0	15.88	0.57	6.55±0.21
2	1.35	0.98	0.0017	0.91	9.6	67.17	0.67	5.21±0.08
3	1.13	0.99	0.0010	0.88	7.3	77.32	0.66	5.04±0.06
4	1.37	1.14	0.0018	0.90	2.9	65.90	0.57	5.20±0.10
5	1.52	1.11	0.0024	0.88	1.6	57.67	0.58	5.04±0.22
6	1.25	0.56	0.0013	0.88	0.7	70.27	1.16	5.07±0.14
7	1.40	3.37	0.0028	0.81	3.6	57.79	0.19	4.67±0.06
8	2.80	18.06	0.0113	0.77	100.0	27.64	0.04	4.46±0.20
Total age = 5.08 Ma; Plateau age = 5.11±0.10 Ma (steps 2-6, 75.7% of ³⁹ Ar)								

GS 175 - Nahal Shezafim (meas. 43/6075; J = 0.006900; Fig. 3b)								
1	4.81	1.24	0.0147	0.52	1.3	10.89	0.52	6.51± 0.90
2	0.70	0.85	0.0013	0.36	4.7	50.83	0.76	4.42± 1.21
3	0.50	0.67	0.0004	0.42	28.3	83.24	0.97	5.17± 0.08
4	0.47	0.78	0.0003	0.41	56.3	88.98	0.83	5.15± 0.07
5	0.47	1.14	0.0004	0.41	81.6	86.51	0.57	5.08± 0.07
6	0.51	2.08	0.0008	0.40	92.8	78.97	0.31	5.02± 0.09
Total age = 5.11 Ma; Plateau age = 5.13±0.08 Ma (steps 3-6, 94.9% of ³⁹ Ar)								

GS 222 - Kokhav HaYarden (base) (meas. 43/6088; J = 0.006900; Fig. 3c)								
1	766.4	2.07	2.4985	28.16	99	3.67	0.31	320±99
2	212.7	1.27	0.6832	10.82	0.4	5.09	0.51	130±13
3	10.22	0.77	0.0319	0.83	5.2	8.09	0.84	10.3± 1.00
4	4.77	0.63	0.0141	0.62	11.0	12.92	1.04	7.66± 0.31
5	1.71	0.62	0.0044	0.43	21.8	25.47	1.04	5.40± 0.14
6	1.03	0.88	0.0022	0.42	45.9	41.30	0.74	5.28± 0.08
7	0.61	1.82	0.0011	0.41	68.1	67.21	0.36	5.11± 0.13
8	0.69	2.89	0.0015	0.42	83.3	61.34	0.22	5.24± 0.10
9	0.88	4.33	0.0029	0.33	89.5	37.14	0.15	4.04± 0.35
10	1.06	5.05	0.0039	0.28	93.5	25.83	0.13	3.42± 0.42
11	2.07	17.79	0.0113	0.01	96.8	0.25	0.04	0.06± 1.06
12	44.31	36.95	0.1453	4.21	100.0	9.49	0.02	51.62± 0.99
Total age = 7.34 Ma; Plateau age = 5.24±0.11 Ma (steps 5-8, 73.3% of ³⁹ Ar)								

Step No.	$\frac{^{40}\text{Ar}}{^{39}\text{Ar}}^a$	$\frac{^{37}\text{Ar}}{^{39}\text{Ar}}^a$	$\frac{^{36}\text{Ar}}{^{39}\text{Ar}}^a$	$\frac{^{40}\text{Ar}^*}{^{39}\text{Ar}}^b$	% $^{39}\text{Ar}^c$	% $^{40}\text{Ar}^{*d}$	K/Ca ^e	Apparent Age (Ma) ^f
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DM 394 - Hirbet Gvul (meas. 42/6340; J = 0.003195; Fig. 3d)

1	6.45	1.93	0.0185	1.11	7.2	17.23	0.34	6.39± 0.35
2	0.89	0.90	0.0006	0.76	28.1	84.95	0.72	4.35± 0.08
3	0.85	1.33	0.0006	0.74	65.0	87.77	0.49	4.28± 0.06
4	0.92	2.48	0.0011	0.75	80.8	81.75	0.26	4.34± 0.13
5	1.10	3.63	0.0021	0.73	89.9	66.63	0.18	4.21± 0.13
6	1.53	13.75	0.0063	0.66	100.0	43.03	0.05	3.79± 0.22
Total age = 4.40 Ma; Plateau age = 4.30±0.09 Ma (steps 2-5, 82.7% of ^{39}Ar)								

GS 223 - Kokhav HaYarden (top) (meas. 44/6383; J = 0.004020; Fig. 3e)

1	9.12	0.94	0.0281	0.87	6.1	9.58	0.69	6.33± 1.26
2	0.79	0.49	0.0005	0.65	41.9	83.07	1.34	4.74± 0.05
3	0.74	0.90	0.0005	0.64	74.9	86.26	0.72	4.64± 0.05
4	0.81	1.89	0.0010	0.63	89.3	77.24	0.34	4.54± 0.18
5	1.13	3.59	0.0028	0.53	94.8	47.28	0.18	3.86± 0.27
6	2.10	5.32	0.0073	0.31	96.5	14.57	0.12	2.21± 0.69
7	4.93	31.50	0.0239	0.13	98.0	2.54	0.02	0.91± 0.57
8	26.22	99	0.1162	0.44	100.0	1.66	0.00	3.16± 1.38
Total age = 4.59 Ma; Plateau age = 4.67±0.07 Ma (steps 2-4, 83.2% of ^{39}Ar)								

DM 522 - Qarne Hittim (meas. 42/6347; J = 0.003195; Fig. 3f)

1	2.85	1.04	0.0072	0.79	7.0	27.53	0.63	4.52± 0.12
2	1.01	1.03	0.0013	0.68	21.3	67.50	0.63	3.93± 0.26
3	0.88	1.02	0.0009	0.67	65.6	76.29	0.63	3.88± 0.05
4	1.03	1.64	0.0016	0.65	81.5	63.60	0.40	3.76± 0.10
5	1.43	2.92	0.0032	0.67	87.6	46.64	0.22	3.84± 0.30
6	2.14	4.22	0.0060	0.67	90.8	31.47	0.15	3.88± 0.57
7	5.62	34.42	0.0253	0.65	96.9	11.52	0.02	3.73± 0.29
8	5.57	31.90	0.0249	0.52	100.0	9.24	0.02	2.97± 0.73
Total age = 3.88 Ma; Plateau age = 3.85±0.14 Ma (steps 2-7, 89.9% of ^{39}Ar)								

Step No.	$^{40}\text{Ar}/^{39}\text{Ar}^a$	$^{37}\text{Ar}/^{39}\text{Ar}^a$	$^{36}\text{Ar}/^{39}\text{Ar}^a$	$^{40}\text{Ar}^*/^{39}\text{Ar}^b$	$\%^{39}\text{Ar}^c$	$\%^{40}\text{Ar}^{*d}$	K/Ca ^e	Apparent Age (Ma) ^f
AH 412 - Tel Kinnarot (meas. 42/6356; J = 0.003790; Fig. 3g)								
1	19.8	1.86	0.0616	1.76	5.8	8.88	0.35	12.0± 0.99
2	1.22	0.79	0.0017	0.76	27.1	62.63	0.83	5.20± 0.22
3	0.95	1.03	0.0009	0.73	66.9	77.60	0.63	5.01± 0.10
4	1.26	2.27	0.0023	0.72	88.8	56.88	0.29	4.89± 0.10
5	1.66	5.26	0.0046	0.67	95.8	40.34	0.12	4.57± 0.35
6	1.86	6.50	0.0053	0.74	98.3	39.93	0.10	5.07± 0.43
7	4.15	44.82	0.0255	-0.17	100.0	-4.08	0.01	-1.16± 1.11
Total age = 5.30 Ma; Plateau age = 5.03±0.13 Ma (steps 2-4, 83.0% of ^{39}Ar)								

DM 479 - Kefar HaNasi (meas. 44/6373; J = 0.004020; Fig. 3h)								
1	0.95	0.54	0.0019	0.40	18.4	42.31	1.19	2.90± 0.04
2	0.69	0.35	0.0007	0.48	58.2	69.78	1.84	3.47± 0.06
3	0.61	0.66	0.0005	0.49	78.0	80.10	0.98	3.53± 0.09
4	0.81	1.51	0.0014	0.49	84.7	60.67	0.43	3.57± 0.17
5	1.14	2.53	0.0027	0.51	88.1	44.44	0.26	3.68± 0.48
6	1.52	4.44	0.0049	0.37	91.0	24.00	0.15	2.65± 0.24
7	1.83	10.62	0.0077	0.29	96.4	16.07	0.06	2.13± 0.26
8	6.93	11.95	0.0249	0.41	100.0	5.94	0.05	2.99± 1.36
Total age = 3.28 Ma; Plateau age = 3.51±0.10 Ma (steps 2-5, 69.7% of ^{39}Ar)								

DM 334 - Neot Golan (meas. 44/6221; J = 0.004030; Fig. 3i)								
1	20.63	1.43	0.0635	1.94	3.3	9.42	0.45	14.06± 0.44
2	0.91	1.18	0.0010	0.68	16.8	74.28	0.55	4.92± 0.08
3	0.80	1.09	0.0007	0.66	53.7	82.28	0.60	4.79± 0.06
4	0.82	1.41	0.0008	0.66	75.7	80.41	0.46	4.79± 0.09
5	0.89	2.02	0.0013	0.65	86.5	72.60	0.32	4.70± 0.07
6	1.10	3.21	0.0026	0.56	92.1	51.06	0.20	4.08± 0.25
7	1.69	4.87	0.0053	0.46	95.5	27.03	0.13	3.31± 0.39
8	2.54	9.94	0.0097	0.38	97.5	14.80	0.06	2.73± 1.08
9	7.48	63.15	0.0431	-0.77	100.0	99	0.01	-5.58± 0.95
Total age = 4.71 Ma; Plateau age = 4.80±0.07 Ma (steps 2-5, 83.2% of ^{39}Ar)								

Step No.	$^{40}\text{Ar}/^{39}\text{Ar}^a$	$^{37}\text{Ar}/^{39}\text{Ar}^a$	$^{36}\text{Ar}/^{39}\text{Ar}^a$	$^{40}\text{Ar}^*/^{39}\text{Ar}^b$	% $^{39}\text{Ar}^c$	% $^{40}\text{Ar}^{*d}$	K/Ca ^e	Apparent Age (Ma) ^f
DM 544 - Har Ram (meas. 44/6239; J = 0.004025; Fig. 3j)								
1	10.37	1.06	0.0322	0.92	12.3	8.89	0.61	6.68± 0.19
2	0.71	0.58	0.0007	0.52	26.4	72.60	1.12	3.74± 0.20
3	0.58	0.56	0.0004	0.49	72.0	83.94	1.15	3.54± 0.05
4	0.62	1.44	0.0008	0.46	86.6	74.94	0.45	3.36± 0.07
5	0.85	3.61	0.0022	0.45	92.0	52.27	0.18	3.23± 0.24
6	0.99	5.30	0.0038	0.23	95.4	22.83	0.12	1.64± 0.55
7	1.92	22.09	0.0131	-0.38	98.5	99	0.03	-2.79± 0.83
8	5.30	61.47	0.0396	-2.11	100.0	99	0.01	-15.42± 1.76
Total age = 3.37 Ma; Plateau age = 3.52±0.09 Ma (steps 2-5, 79.7% of ^{39}Ar)								

GS 204 - Kabul (meas. 44/6231; J = 0.004020; Fig. 3k)

1	96.59	4.71	0.3155	3.67	0.8	3.80	0.14	26.43±22.69
2	1.61	0.76	0.0038	0.53	24.5	32.99	0.86	3.85± 0.20
3	0.72	0.73	0.0008	0.52	67.2	71.63	0.88	3.73± 0.05
4	1.06	1.33	0.0021	0.51	78.4	48.49	0.49	3.71± 0.37
5	1.63	3.10	0.0059	0.08	81.9	4.80	0.21	0.57± 1.27
6	2.15	6.48	0.0078	0.29	84.0	13.54	0.10	2.11± 1.01
7	1.73	15.78	0.0090	0.21	93.9	12.17	0.04	1.53± 0.38
8	3.85	34.57	0.0192	0.68	100.0	17.66	0.02	4.92± 0.62
Total age = 3.66 Ma; Plateau age = 3.76±0.14 Ma (steps 2-4, 77.6% of ^{39}Ar)								

^a The isotope ratios given are not corrected for Ca and K derived Ar isotopic interferences, however ^{37}Ar is corrected for decay using a half-life of 35.1 d. The ratios for line blanks are of atmospheric Ar composition.

^b $^{40}\text{Ar}^*/^{39}\text{Ar}$ is the ratio of radiogenic ^{40}Ar to K-derived ^{39}Ar . It is corrected for atmospheric argon and interferences using the following factors: $(^{40}\text{Ar}/^{36}\text{Ar})_{\text{air}}=295.5$; $(^{39}\text{Ar}/^{37}\text{Ar})_{\text{Ca}}=12.0\times 10^{-4}$; $(^{36}\text{Ar}/^{37}\text{Ar})_{\text{Ca}}=2.453\times 10^{-4}$; $(^{40}\text{Ar}/^{37}\text{Ar})_{\text{K}}=1.9382\times 10^{-4}$.

^c Cumulative percent of ^{39}Ar released by the fractions.

^d Percent of the total ^{40}Ar in the fraction that is radiogenic.

^e Weight ratio calculated using the relationship: $\text{K}/\text{Ca}=0.65\times(^{39}\text{Ar}_{\text{K}}/^{37}\text{Ar}_{\text{Ca}})$.

^f Ages calculated with a total decay constant of $5.543\times 10^{-10}\text{y}^{-1}$. Uncertainties are quoted at the 1 level. Summations of ages are weighted by amounts of ^{39}Ar . For total fusion, plateau, and other ages, uncertainties reflect a relative uncertainty of ±1% in J value. The monitor used was HD-B1 biotite (Fuhrmann et al., 1986) with a $^{40}\text{Ar}/^{39}\text{Ar}$ age of 24.7 Ma.

Table 7:

Summary of $^{40}\text{Ar}/^{39}\text{Ar}$ total gas and plateau ages of measured Cover Basalt samples. Previous K-Ar ages of the same samples are also presented.

Location	Coordinate (Israel Grid)	Sample No.	Total Gas Age (Ma)	Plateau Age (Ma)	K-Ar Age (Ma)
LOWER GALILEE					
<u>Base</u>					
Nahal Yisaachar	19710/21860	DM 393	5.08	5.11±0.10	4.6±0.1
Nahal Shezafim	18470/21980	GS 175	5.11	5.13±0.08	5.3±0.2
Kokhav HaYarden	19925/22211	GS 222	7.34	5.24±0.11	5.2±0.1
<u>Top</u>					
Hirbet Gvul	19820/21860	DM 394	4.40	4.30±0.09	4.2±0.1
Kokhav Hayarden	19917/22211	GS 223	4.59	4.67±0.07	4.5±0.3
Qarne Hittim	19330/24520	DM 522	3.88	3.85±0.14	4.1±0.2
KORAZIM BLOCK					
<u>Base</u>					
Tel Kinnarot	20080/25300	AH 412	5.30	5.03±0.13	5.1±0.3
<u>Top</u>					
Kefar HaNasi	20710/26430	DM 479	3.28	3.51±0.10	3.5±0.3
GOLAN					
<u>Base</u>					
Neot Golan	21520/24315	DM 344	4.71	4.80±0.07	4.9±0.1
Har Ram	22335/29430	DM 544	3.37	3.52±0.09	3.9±0.4
WESTERN GALILEE					
Kabul	17120/25110	GS 204	3.66	3.76±0.14	3.9±0.5

Table 8:

Summary of $^{40}\text{Ar}/^{39}\text{Ar}$ and K-Ar ages obtained on Cover Basalt samples at different part of the sequence. Ages in m.y.; number of sites in brackets.

	Previous K-Ar	Previous Ar/Ar	New Ar/Ar
Top of sequence	4.5-3.5 (16)	4.5-3.3 (4)	4.7-3.5 (4)
Base of sequence	5.5-4.3 (22)	5.5-4.0 (9)	5.2-4.8 (5)
Within the sequence	5.3-3.6 (44)	5.0-3.5 (8)	3.8-3.5 (2)

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