

II - KARST AND CAVES OF ISRAEL (A. Frumkin)

II. 1 - Introduction

Israel displays a gradient of karst features from the intensive karstification of Lebanon in the north to practically no karst in Elat region at the southern Negev desert (GERSON, 1976). This is attributed mainly to the climatological gradient from alpine-mediterranean climate in the Lebanon - Hermon mountains in the north, with precipitations >1 000 mm/year, to the extremely arid southern Negev, with <50 mm/year. Another factor is the southward decrease in carbonates/clastics ratio of the Phanerozoic stratigraphic section due to the increasing distance from the Tethys Sea which deposited the significant carbonates.

Carbonate rocks outcrop in some 75% of the hilly regions of Israel. They are predominantly of Jurassic to Eocene age. However, much of the carbonates contain marls which inhibit extensive karst development, promoting the dominance of fluviokarst features. Another inhibiting factor is the abundance of faults in the Hermon, Galilee and Samaria regions. The faults are thought to constrain the temporal and spatial continuous underground flow, limiting the development of large caves in these regions.

Most limestone caves are relict phreatic conduits and voids, which do not show any genetic relation to subaerial topography. Today these caves are either dry or experience vadose dripwater. These caves have possibly developed under moister conditions than predominate today. Some of them have been sealed from the surface until opened by recent construction activity. They may contain valuable paleoclimatic records (FRUMKIN *et al.*, 1994). Vadose caves are also common, and typically experience some water flow and active dissolution during the rainy season. These are mostly composed of vertical shafts with rare horizontal sections.

The unique rock salt karst of Mount Sedom exhibits the largest salt caves known in the world (Malham Cave, 5 685 m).

Some sea caves, attributed mainly to wave action with limited dissolution, appear in chalk and in the "Kurkar" sandstone ridge along the Mediterranean coast.

Paleokarst is common in the stratigraphic section, and is probably related to humid paleoclimates.

Israel is especially rich in man made caves sustaining abundant fauna, but are beyond the scope of this review.

II. 2 - Major karst regions

The major karst regions of Israel are briefly reviewed below (fig. 1, 1-7).

Hermon (1). The higher part of Mount Hermon, on the northern end of Israel, displays distinctive alpine karst features. The elevation within Israel's border reaches 2 220 m, and snow covers the higher parts several months a year. Massive Jurassic limestone, several hundred meters thick, gives rise to developed holokarst with doline fields and poljes. However, the intensively fractured rock limit the number and extent of large caves. Only two caves are known above 2 000 m s. l [Me'arat (= Cave) Pitulim and Me'arat Mizpe Shelagim], both vadose and only tens of meters long. The temperature in depth of these caves does not exceed a few degrees C even in summer, so they form a unique ecosystem in Israel. Known caves at lower elevations on Mount Hermon flanks are not larger than tens of meters too, but they include phreatic features, indicating longer evolution period.

The basaltic Golan Heights (Ramat Hagolan), south of Mount Hermon, exhibits some pseudokarst features (INBAR, 1984).

Galilee (Galil) (2). The Galilee mountains is the major karst region of northern Israel, developed on Cretaceous to Eocene carbonates. Mediterranean fluviokarst is developed across the whole region, while the upper Galilee, especially around Mount Meron, displays some mature karstified areas (GERSON, 1974). Of these, Mount Peqi'in is notable for its developed doline karst landforms with highest density of limestone vadose shafts in Israel. Two ponors drain large karst areas: Me'arat Pa'ar, in the bottom of a large doline, and Zomet Meron sink. The largest caves of the Galilee are: Me'arat Sharakh; Me'arat Alma - a tectonic cave altered by phreatic dissolution; Me'arat Jermak - a vertical vadose shaft system, the deepest in Israel; Me'arat Bereniqi - a relict phreatic maze.

The Galilee is the main part of Israel where diving is needed to explore some caves. Me'arat En Nur (spring of Tabgha) is an underwater resurgence cave on the northwest coast of Lake (Yam) Kinneret. Other short spring caves with perennial flow are 'Enot Enan, 'En Tamir and 'En Amal. Sea caves with dissolution features are developed in Rosh-Haniqra.

Karmel (Mount Carmel) (3). The Karmel ridge is built mainly of Upper Cretaceous carbonates. Fluviokarst is common, while karstic closed depressions are rare. A major active fault along the north-eastern edge of the ridge seems to inhibit karst development on this side. Relict phreatic caves are common mainly along the western border of the ridge, while vadose caves are less common. The longest cave is Me'arat Ornit - a dry phreatic maze.

Samaria (Shomeron) (4). Most karst landforms in Samaria appear on Cretaceous limestone and dolomite. Western Samaria is rich in small caves with relict phreatic and active vadose features. The largest cave is Me'arat Nahal Qana - a tectonic maze with a phreatic chamber (FRUMKIN). The Ram'alla anticline at eastern Samaria is poor in large caves in its northern part, where it is dissected by large transversal faults. However, large caves do appear on its southern part, which is structurally similar to the Judean (Yehuda) mountains. Of special interest is Nahal Delaya, where three large caves are grouped together (FRUMKIN, 1991).

Few caves are known across the Eocene carbonates of the northern Samaria syncline, although it serves as a major karst aquifer of Bet-She'an valley and Shekhem region. This region displays the largest tectonokarst feature in Israel - the Sanur polje.

The limited outcrop of Jurassic limestone display extensive karren features, but only few small caves. Karst landforms appear rarely in Neogene conglomerates of eastern Samaria.

Judea (Yehuda) (5). Karst features appear here on Cretaceous to Eocene carbonates. Much of the upper erosion surface of Judea Mountains was formed by karst denudation (FRUMKIN, 1993). Fluviokarst is most common, but north of Jerusalem there are some areas of internal karst drainage, and also a doline field with 12 known vadose shaft systems (FRUMKIN, 1986b). Lack of major faults has promoted the development of long and stable subsurface flow routes in the phreatic zone, allowing the development of the largest and most abundant limestone caves in Israel. The known phreatic caves are relict, sometimes forming three dimensional maze, such as Me'arat Hariton (Charitun) - the longest limestone cave in Israel, with 3 450 m of mapped passages. Most large caves (Makukh, Hameraglim, El-Gai, Masaia, Pitria, Hariton, Qneitra) appear in massive Turonian limestone along the eastern monocline of Hebron anticline. The longest cave in the western monocline is the Me'arat Tur Safa, near Hebron. The geologically most studied cave in Israel is probably Me'arat Soreq (BAR-MATTHEWS *et al.*, 1991; EVEN *et al.*, 1986). This show cave is profoundly decorated with speleothems. Natural caves in chalk are relatively rare. The longest is Me'arat Niqbot Hamaim in the Eocene chalk of Hashefela region (FRUMKIN, 1990a). The largest limestone chamber in Israel (200 x 100 m) is Me'arat Atarot, in northern Jerusalem.

Judean Desert (Midbar yehuda) - Negev desert (6). This region is arid, with precipitation lower than 200 mm/year. Therefore active karst processes are mostly limited to the micro scale. Judean desert is a rain-shadow desert east of Judea mountains. The mountains (precipitation of up to 600 mm/year) are the input zone of groundwater discharging along Dead Sea (Yam Hamelah). Such circulation has probably formed the relict phreatic caves found in Turonian limestone west of the Dead Sea. The larger caves are Me'arat Ha'igrot, Qanna'im, Kidod and Zavoia.

Unlike the Judean desert, the Negev desert is part of the global saharan arid belt. Large caves are rare, although carbonate rocks are common. Water was probably insufficient for karst development even during humid phases of the Pleistocene. The largest cave is Me'arat Ashalim in the northern Negev - a ramiform relict system in Turonian limestone. Small caves in Ma'ale Hameshar are attributed to deep waters rising along faults. Karstic caves are not known in the extremely arid southern Negev.

Table 1 - The largest and deepest caves of Israel (after Frumkin, 1986a).

Largest caves			
Cave = Me'arat	Area	Rock	Length (m)
Malham	Mt Sedom	Salt	5 685
Charitun	Judean Mt	Limestone	3 450
Sedom	Mt Sedom	Salt	1 799
Colonel	Mt Sedom	Salt	1 448
Zekhukhit	Mt Sedom	Salt	1 135
Falafel	Mt Sedom	Salt	700
Qolno'a	Mt Sedom	Salt	695
Araq Na'saneh	Samarian Mt	Limestone	621
Peteq	Mt Sedom	Salt	524
Alma	Galilee	Dolomite	496
Deepest caves			
Cave	Area	Rock	Depth (m)
Jermaq	Mt. Meron Galilee	Dolomite	157
Malham	Mt Sedom	Salt	135
Colonel	Mt Sedom	Salt	127
Alma	Galilee	Dolomite	108
Al Husfi	Samarian Mt.	Limestone	100
Zekhukhit	Mt Sedom	Salt	99
Peqi'in	Galilee	Limestone & Dolomite	93
Notsa	Mt Sedom	Salt	90
Sedom	Mt Sedom	Salt	85
Bu'ah	Mt Sedom	Salt	81

Mount Sedom (7). Mount Sedom salt diapir is extensively karstified in spite of its extremely arid climate due to the high solubility of rock-salt. Some 100 caves have been studied, all of which developed during the Holocene (FRUMKIN *et al.*, 1991). The cave are branchwork vadose multilevel channels (FRUMKIN, 1994b). The denudation and downcutting rate in the salt caves are some of the most rapid in karst (FRUMKIN, 1994a; FRUMKIN & FORD, 1995). Me'arat Malham is the longest salt cave known in the world, with 5 685 m of mapped passages. Other caves longer than 200 m: Me'arat Sedom, Colonel, Dorban, Zekhukhit, Liquid Crystal, Italkit, Buah, Dud, Zaqif, Ionim, Karbolot, Lehavim, Lashleshet, Mifgash, Mifratsim, Mirpeset, Notsa, Nahash, Sedeq, Falafel, Parsafonim, Peteq, Tsinor, Qolno'a and Qupa.

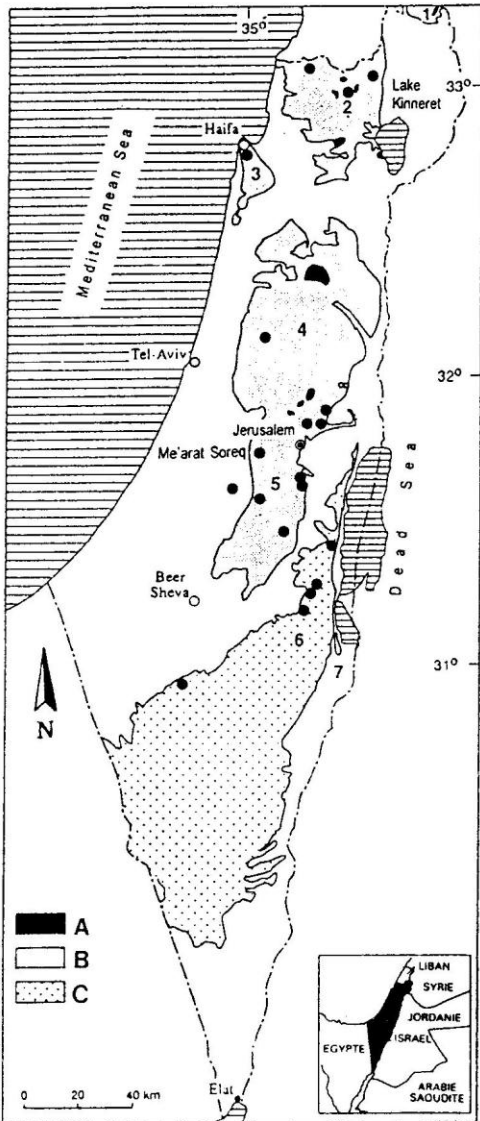


Fig. 1 - Karst regions of Israel. A = karst depressions with internal drainage. B = mediterranean type of karst. C = arid zone with carbonate rocks. ● = caves longer than 200 m, listed from north to south. 1 = Hermon; 2 = Galilee: caves Sharakh, Alma, Jermak, Bereniqi; 3 = Karmel: Me'arat Ornit; 4 = Samaria: caves Nahal Qana, Me'arat Na'asaneh, Yogev; 5 = Judea: caves Makukh, Hameraglim, El-Gai, Atarot, Masaia, Pitria, Hariton, Tur Safa, Qneitra. To the west of Judea is the Me'arat Niqbot Hamaim; 6 = Judean Desert - Negev desert: caves Ha'igrot, Qanna'im, Kidod, Zavaa, Ashalim; 7 = Mount Sedom (After Frumkin, 1994).

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