המכון הגיאולוגי
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טל. 02-5314211 , פקס. 02-5380688

Paleoclimate conditions in the central and northern Negev Desert during the Pleistocene

Avner Ayalon, Miryam Bar-Matthews, Anton Vaks

Annual report, Submitted to the
Earth Sciene Research Administration,
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Introduction

Israel is located in the Eastern Mediterranean (EM) region, within the transition zone between a humid climate in the north and extremely arid climate in the south and southeast. The desert margins were, and still are highly vulnerable to climatic changes (e.g., Goodfriend and Magaritz, 1988; Vaks et al., 2003). Even small shifts in the climate conditions can have a tremendous impact on the temperature gradients and the rainfall amount.

The arid areas of the Levant can be divided into two types:

a) The local 'rain-shadow' deserts, located on the eastern flanks of the mountain ridges, along the Dead-Sea transform. The temperatures on the eastern side of the central ridge of Israel are usually warmer by several degrees relative to the western side. During cool pluvial glacial intervals, the desert boundary effectively migrated further south or east from its present-day location on the eastern flank, whereas interglacial periods appear to have been similar to the present with the desert boundary at the same position (Vaks et al., 2003).

b) The Negev Desert in southern Israel and the deserts in Sinai and Southern Jordan are a part of the Saharo-Arabian desert belt, formed by the sub-tropical high-pressure zone located mainly south of latitudes 30-31°N. The vast expansion of the Sahara Desert to the south during the last glacial maximum, the increased humidity in the Sahara region during the Early Holocene, and the aridification of the Sahara during the last 4000 years were most probably caused by changes in the summer monsoon intensity (e.g., Street & Grove, 1979; Gasse & Van Campo, 1994; Almogi-Labin et al., 1998). However, little is known on the migration of the northern boundary of Saharo-Arabian desert belt in the Eastern Mediterranean region.

Purposes:

1. To identify caves containing speleothems and tufa deposits in the Central and Northern Negev;
2. To date periods of speleothems growth using the well established alpha spectroscopy U-Th method;

3. To develop in our lab the new technique of accurate, very high resolution U-Th dating of speleothems using the most elaborate equipment: Multiple Collector Inductively Coupled Plasma Mass Spectrometer (MS ICP MS);

4. With the timing of speleothems and tufa deposition from Southern Israel to reconstruct the paleo hydrological condition during the Mid-Late Pleistocene and Holocene.

Preliminary results

Developing of analytical techniques

During the present stage of the study much effort was put into collecting samples and petrographically identifying and separating fine growth laminae for dating purposes.

Dating: In collaboration with Nataliya Teplyakov we modified a protocol for chromatographic separation between U and Th. This includes the following steps:

1. Weighing sample.
2. Sample dissolution with 7N HNO_3
3. Centrifuge leachate from any detritus.
4. Reserve leachate, and add 7N HNO_3 to form slurry.
5. Add 1-2 ml of HF, and allow to dissolve.
6. Evaporate to near dry, and add 7N HNO_3, leave to dissolve.
7. Add carbonate leachate back to the beaker containing the dissolved residue.
8. Weigh spike into the dissolved residue and allow the sample and the spike to equilibrate.
9. Evaporate to dryness, add 7N HNO_3 to form clear solution.
10. Column procedure:

a. Add resin into pre-washed columns, and wash 3 times with 6N HCl, and twice with TD H_2O.

b. Precondition the columns with 7N HNO_3.

c. Load sample

d. Elute 3 times with 2ml 7N HNO_3

e. Elute with 1.5 ml 6N HCl

f. Collect Th with 3.5 ml 6N HCl

g. Elute with 1.5 ml 1N HBr

h. Collect U with 3.5 ml 1N HBr.

i. Evaporate to dryness.

j. Add 2-3 ml HNO_3 and transfer to centrifuge tubes.

k. Analyze U concentration with ICP-MS.

The dating procedure, using the MC ICP MS, was developed in collaboration with Ludwik Halicz. This includes the measurements of the isotope ratios of ^{234}U, ^{235}U, ^{236}U (spike) to ^{238}U, using an internal standard of natural ratio of $^{235}U/^{238}U$, the measurements of thorium isotope ratio ^{229}Th (spike), ^{230}Th, ^{232}Th using an external standard of the natural ratio of $^{235}U/^{238}U$.

Dating results

Detailed field studies have enabled us to locate caves from Central and Northern Negev that contain numerous speleothems and several tufa exposures. These are summarized in Fig. 1 and Table 1.

Dating speleothems using the U-Th method is time consuming and expensive. We applied a logic in which we dated first the outermost laminae (the youngest in age) in order to determine whether its growth occurred within the last ~400,000 years, the limit of the U-Th dating method. Moreover, dating of the outermost laminae enables us to determine the last episode of speleothem growth in the present-day desert. During the latter stage we dated also older laminae in some speleothems. So far we dated 101 samples, from which 14 were dated by the newly developed most elaborate method of the MC ICP MS and 87 by the alpha spectroscopy method. The samples were collected from eight caves located at the ridge crests in the northern Negev from the "rain-shadow" area of the north-eastern Negev, caves from the central Negev and two tufa exposures (Table 1, Fig. 1). At present, most of the caves are almost completely dry with no speleothem formation.

Table 2 summarizes the preliminary ages using U-Th alpha spectrometry, and U-Th MC ICP MS.

Northern Negev ridge crests and western slopes:

The caves in the Northern Negev (Fig. 1 and Table 1; No 1-4), Ma'ale Deragot (MD), Tzavoa (TZ) and Izzim (IZ) are located within the 120-300 mm isohyets.

MD caves represent a large cave system, within Shivta (Turonian) and Tamar (Cenomanian) formations. The caves are exposed within a quarry and are the northernmost caves, located at the border between the semi-arid eastern Mediterranean type climate and the Negev desert with 260-300 mm annual rainfall. This is the only site where a small conical stalactite was dated as late Holocene (alpha spectrometry age of 1.7 ± 1.4 kyr). Other ages are: ~25, 37, 65 and 151 kyr. These ages represent short deposition periods during marine isotope glacial stages. Ages of the other speleothems from these caves are close to, or above the limit of the dating method.

TZ cave is located within 140-160 mm isohyets. The cave is a large karstic system (hundreds of meters length) within Shivta Formation, very rich with speleothems. The cave form labyrinths with several natural openings and contain numerous speleothems. Presently there are some sites where recent dripping of water occurs during the winter. However, we did not yet identify any recent speleothem deposition, and moreover, wet speleothems are very porous and eroded. On eighteen speleothems 26 age determinations were performed. The youngest sample is of Early Holocene (8.5±2.0 kyr, alpha spectrometry age, Table 1), while the other ages cluster at ~ 17-20 kyr, 25-30 kyr, 35-37 kyr, 44-51 kyr, 55-59 kyr. All these ages indicate that speleothems growth occurred mainly during intervals within the last glacial. One sample was dated at ~112 ± 17 kyr, and probably was deposited during interglacial stage MIS 5. No older speleothems were found.

IZ cave is an average size cave (few chambers with overall length up to 100 meters), located within a quarry in Shivta Formation, at 120-140 mm isohyets. The cave contains numerous speleothems, with large calcite crystals (up to few cm in size). The ages of the 4 samples dated from this cave are older than the limit of the dating method. At this stage, because all other speleothems have similar petrographic appearance to those dated, we decided to look for speleothems with laminated petrography similar to TZ and MD caves.

Northern Negev, rain-shadow area

The caves and tufa outcrop in the "rain-shadow" area of the Northern Negev (Fig. 1, Table 1 No. 5-7, 12) are Kanaim Cave (KN), Hol-Zach Cave (HZ), Makhtesh Qatan outlet Cave (MKTC) and Makhtesh Qatan tufa outcrop (MKT) located within 50-90 mm isohyets.

KN Cave located within the 70-90 mm isohyets, within Shivta Formation, is a large karstic system (hundreds of meters length) and has one natural opening. Speleothems are found in one chamber, about 80-100 meters from the entrance. Fourteen ages were performed on eight speleothems. The ages form two main clusters: glacial MIS 6, 145-183 kyr (4 samples), and MIS 7 and 8, 230-260 kyr (3 samples). Some speleothems are close to, or above the limit of the dating method. No speleothems younger than 145 kyr were found.

HZ Cave is located within 70-90 mm isohyets, within a quarry in Shivta Formation. The cave did not have a natural opening before quarrying. Most of the cave is filled with rock collapse and the speleothems are found in one small chamber. Six samples were dated and all ages are of interglacial MIS-5, 115-132 kyr.

One tufa sample from MKT was dated, giving an age 140 kyr (glacial MIS 6). The speleothems from small cave in the MKTC Cave (Shivta Formation) were not dated yet.

Central Negev

The caves and the tufa outcrops in the central Negev (Fig. 1 and Table 1, No. 8-11 and 13-19) are: Ashalim Cave (ASH), Mitzpe-Ramon Cave (MR), Even-ve-Sid Mitzpe Ramon Quarry (ESID, SHAR), Wadi Lotz Cave (LOTZ), and two tufa outcrops in Ein-Avdat (EA) and Ein Aqev (AQ).

The ASH Cave, located in Shivta Formation, is part of a large karstic system (hundreds of meters length) with one natural opening. The annual rainfall in the area is 90-120 mm. The cave is very rich in speleothems, with very special stratigraphy (Figs. 2a,b). The upper layer of most of the speleothems is dark, sometimes laminated, while the lower layer is yellowish, massive and composed of large (20-50 mm) crystals. Within the upper dark layer and between the dark and the yellowish layer many thin white micritic laminae (1-3 mm thick) can

be observed, and they may possibly mark hiatuses. About 1 km NW from this large cave, another small cave was found, containing speleothems with almost identical petrography. Twenty-two age determinations were performed on eighteen speleothems and the ages indicate that most speleothems are close to, or older than the dating limit. The outermost thin (5mm) laminae taken from two speleothems yield an age of 110-118 kyr (interglacial MIS-5) using alpha spectrometry, an age of 386±10 kyr (interglacial MIS-11) using MC-ICP-MS.

The MR Cave, located in Cenomanian Tzofit Formation, is a small cave, 35 meters long, with one natural opening. The speleothems, mainly flowstone, are located in two chambers 25-35 meters from the entrance. Most of the speleothems have coarse calcite crystals (10-40 mm), some are finer grained crystals forming laminae of 5-25 mm thick. Nine age determinations were performed on five speleothems by means of alpha spectrometry; all are close to, or above the limit of the dating method. Most of the speleothems from this cave contain very low uranium concentration (about 100 ppb).

The ESID and SHAR speleothems are located within quarries, in Cenomanian Tamar Formation. The rock contains numerous small karstic voids and fissures partly filled with speleothems and Terra Rosa soil. The presence of Terra Rosa is indicative to wetter conditions in the past. Under present-day conditions, soil typical of arid region develops on the surface. Three samples were dated by means of MC-ICP-MS. The age of the top lamina of one of the speleothem is 161.8±0.6 kyr (glacial MIS 6), while two other speleothems are older than the limit of the dating method. The petrography of the relatively younger speleothem is laminated (Fig. 2c) and these laminae contain 500-2000 ppb U, much higher than the 60-150 ppb U typical of the older coarse 10-50 mm calcite crystals speleothems (Fig. 2c).

Wadi Lotz (LOTZ) Cave is located within 90-120 isohyets, in Eocene Nizzana Formation. The cave is a vertical pit, 15 m high and eroded roof causing the speleothems to be exposed to the atmosphere. The cave has underground extension (very narrow corridor). The petrography of all the speleothems is of coarse crystal. No speleothems were dated yet.

intervals within the last glacial period and the Holocene, the "rain shadow" area of the Northern Negev and the central Negev were dry. However, intensive tufa deposition occurred in Ein-Avdat springs as was found also by Schwarcz et al. (1979). It is necessary to study in more details the tufa deposition in order to understand this "discrepancy". Most of the speleothem deposition in Central Negev occurred at time periods older than the alpha spectrometry U-Th dating method (~250 kyr).

There is a very marked petrographic boundary between the older than 250 kyr speleothems with the large calcite crystals and the relatively younger smaller sized crystal speleothems. It is possible that this sharp boundary mark very different hydrological regime.

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Table 1:

Area	Site #	Name	Symbol	Location	elevation	mm rain	depth below the surface
Northern Negev, ridge crests and western slopes	1	Ma'ale-Deragot *Eastern Quarry*	*MD(1)*	*1575 / 0797*	*630-720*	*280-300*	*2-90*
	2	Ma'ale-Deragot Western Quarry	MD(3)	1545 / 0780	600-650	260-280	2-50
	3	Tzavoa Cave	TZ	17185 / 06865	550	140-160	10-40
	4	Izzim Cave, Aroer Quarry	IZ	15615 / 06096	500	120-140	10
Northern Negev, rain shadow (eastern slopes)	5	Kanaim Cave	KN	1787 / 0786	250	70-90	30-40
	6	Hol-Zach Cave, Hol-Zach Quarry	HZ	1692 / 0628	180	70-90	30
	7	Machtesh-Ha-Katan outlet Cave	MKTC	1710 / 0401	sea level	50-70	surface-4
Central Negev	8	Ashalim Cave	ASH	1251 / 0393	400	100-120	10-25
	9	Mitzpe Ramon Cave	MR	*1302 / 0023*	*850*	*90-120*	*15-25*
	10	Even-Ve-Sid Mitzpe Ramon Quarry	ESID, SHAR	13170 / 0056	800	90-120	2-7
	11	Wadi Lotz Cave	LOTZ	1093/ 9869	900	90-120	surface-2
Spring Tufa samples	12	Machtesh-Ha-Katan	MKT	1694 / 0404	30	60-80	surface
	13	Ein-Avdat	EA	1280/0270	400	90-100	surface
	14	Ein-Aqev	AQ	1320/0224	400	90-100	surface
	15	Ein-Rachel		1667/0027	Sea level	30-50	surface
	16	Moa		1656/9948	30	30-50	surface
	17	*Ein Tamid*		*1690/0247*	*-20*	*30-50*	*surface*
	18	Ein-Zach		1695/0254	-30	30-50	surface
	19	Ein-Yahav		1680/0029	-20	30-50	surface

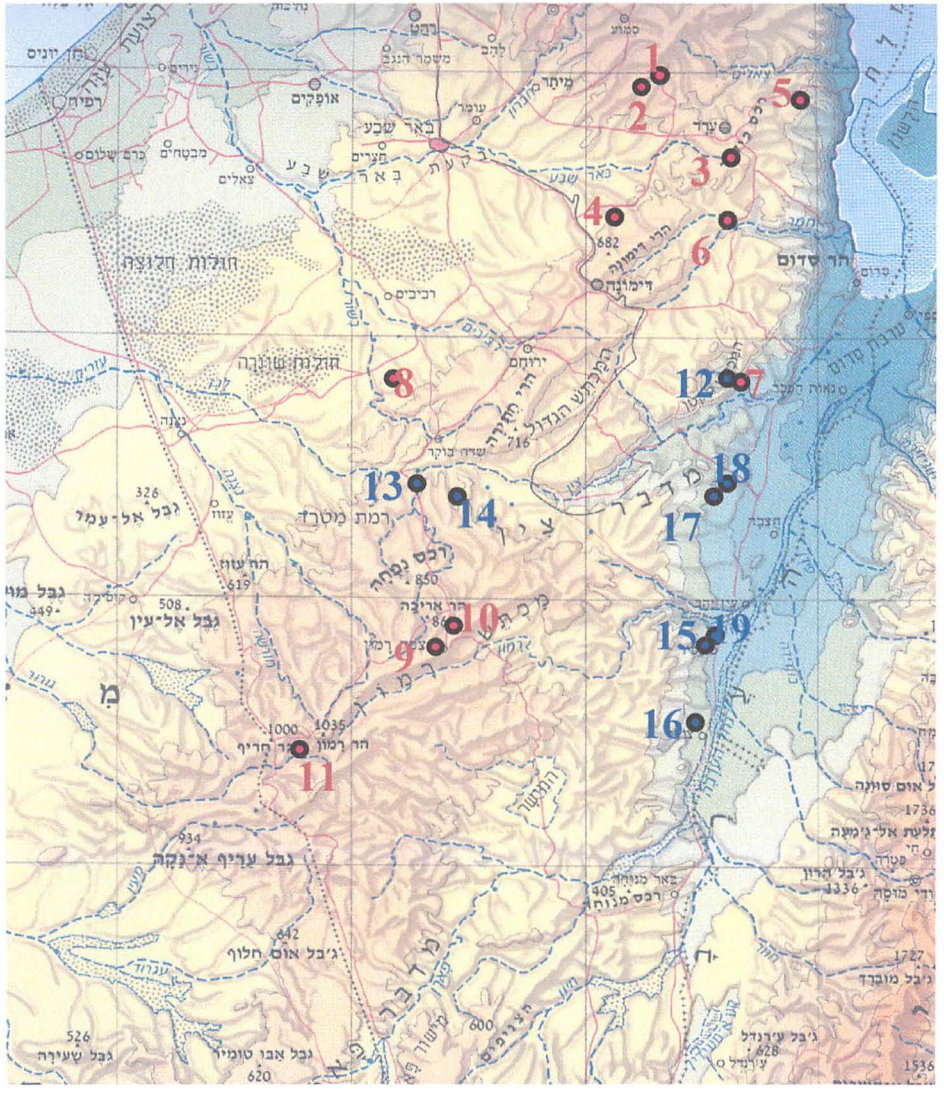
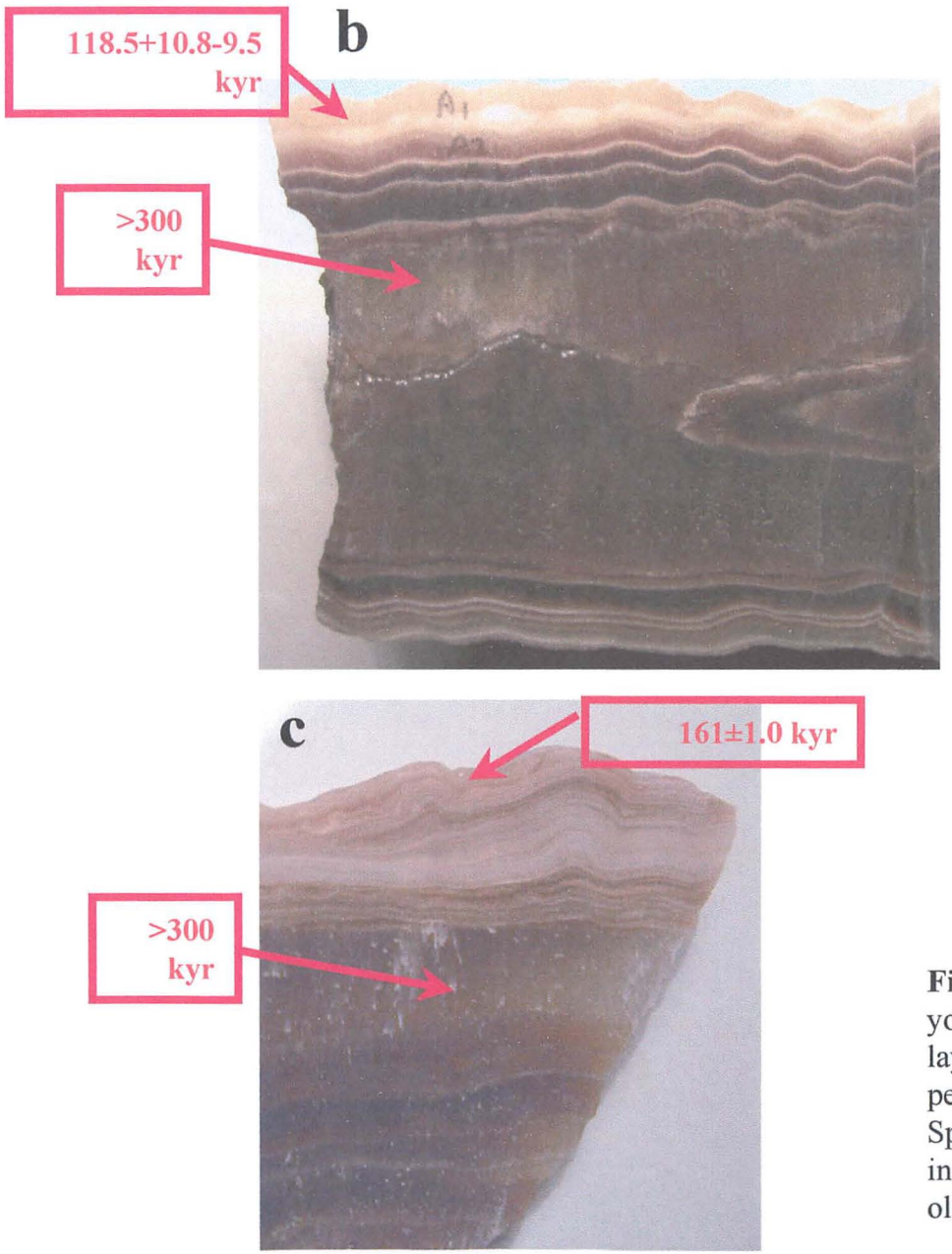


Fig. 1: Location map. The number in red marks caves and caves within quarries. The numbers in blue mark tufa exposures



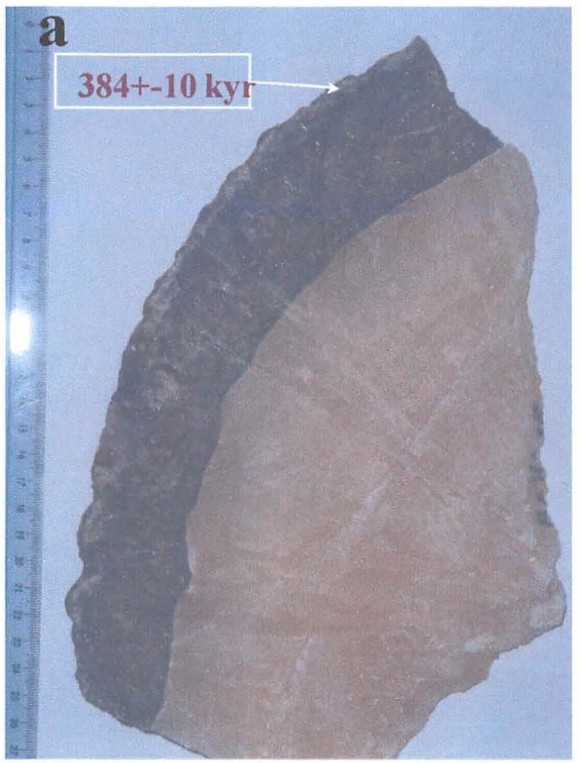


Fig. 2: Speleothems from ASH Cave showing the darker younger layer and the older yellowish layer (a). The top layer of a speleothem from ASH cave showing laminated petrography (b). The older portion contain larger crystals. Speleothems from ESID quarry showing thinner lamination in the top younger part, and coarser crystals in the bottom older part

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16. Abstract (Limit 200 Words)

Speleothems deposition in karstic caves occurs when water reach the unsaturated zone. Several caves, rich with speleothems, were discovered in the Negev desert. However, under present-day conditions no speleothems deposition occurs south of isohyets 260-300 mm. The existence of speleothems in the desert Negev caves clearly indicates that in the past conditions were wetter. One of the purposes of the present study is to date period of speleothems growth from the Northern and Central Negev, as indicators for wetter climatic conditions in the past.

Preliminary U-Th ages reveal pluvial intervals, during MIS 3-4 at 25, 37, 65, and at 150 kyr. In a cave located 20 km south within 140-160 isohyets, one speleothem was dated to the early Holocene. These pluvial periods are associated with wetter interval in central and northern Israel. In caves from the "rain shadow" area of the Northern Negev, and in the central Negev, within isohyets 60-120 mm, no deposition occurred after interglacial MIS 5 (i.e., 115-132 kyr). Speleothems were deposited during MIS 6 (145-183 kyr). Thus, while wetter conditions prevailed in the Northern Negev the "rain shadow" area of the Northern Negev and the central Negev were dry. Most of the speleothem deposition in Central Negev occurred at time periods older than the alpha spectrometry U-Th dating method (~250 kyr).

17. Keywords

paleoclimate, Negev Desert, speleothems, U-Th dating

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