

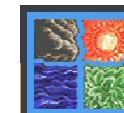
# **EARSeL 6 Workshop, Field trip: Makhtesh Ramon Geological Window, hyper-spectral Calibration site**

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## PROGRAM

### ■ Date and Time

- Saturday, March 21, 2009, Starts 8.00 Ends 20.00 (Tel Aviv)

### ■ Time table:

- 8.00 Departure (after breakfast at the hotels)
- 10.00-11.00 Ramon Visitors Center
- 11.30-12.00 Coffee break
- 11.30-14.30 Geological overview and hyperspectral measurements at nearby sites across Makhtesh Ramon, which discloses various igneous, sedimentary and metamorphic lithologies
- 15.00-16.00 Lunch at the Bërot campground
- 16.30-17.30 Sunset over the carpentry
- 20.00 Arrival to Tel Aviv

## MAKHTESH RAMON AS A SUPER SITE FOR CALIBRATION AND VALIDATION OF **IS** SENSORS

Makhtesh Ramon (MR) is one of the most interesting and powerful sites for HSR sensor calibration worldwide. The growing demand for an ideal site worldwide is expanding as more sensors are used and fewer sites are available.

Makhtesh Ramon is located in southern Israel, within the central Negev area. The area's climate is classified as arid (30 mm annual precipitation). Structurally, the area (25 km long, 7 km wide) is an anticline with an eroded central valley, mostly drained by a single creek. Steep walls (400m height) bound the valley with friable sandstone at the bottom and more resistant limestone and dolomites at the top. Makhtesh Ramon shows a continually exposed section dating from the Middle Triassic to the Middle Eocene. The exposed area is rather flat and consists of pure mineralogical exposures consisting of kaolinite, montmorillonite, calcite, dolomite, marl, gypsum, basalt, tuff, andesite, basanite, chert, sandstone, and iron oxides (hematite, goethite), which can all be found within a short distance.

Due to the arid conditions, only minor vegetation occurs within the MR area and less soils. The area is mostly free of clouds throughout the year, and several weather stations that collect information on a diurnal basis have been dispersed throughout the area. The MR area is known as one of the most important mineralogical sites in Israel and has been called a "laboratory in nature." The area has been declared a Reserved National Geology Park, and it possesses very interesting mineralogical variations within a small area, which attracts the attention of many students

and researchers worldwide. It is located about two hours driving time from Tel Aviv and is consisted of many accommodations possibilities around.

Two main scientific centers equipped with state-of the art meteorological stations and satellite receiving station are situated within the Makhtesh Ramon area. More than 200 scientific papers and reports have been published about the MR area and its nature (geology, climatology, ecology and more). Precise, high-scale maps, representing the geology, pedology, geomorphology, and topography of the area are available in both hard and digital formats. A large archive of HSR data is available for the Makhtesh Ramon area that includes variation of sensors (airborne and space borne) such as AISA-ES, GER 63, CASI and DAIS-7519, CHRIS-PROBA, ASTER and Hyperion. Recently a pixel by pixel (10m) ground spectral map of selected areas along the Makhtesh Ramon was generating using ground ASD and extensive laboratory analyses. The map provides stable and precise information for ground truthing any sensors. Further work is being done to cover the entire area with 10 by 10 meter ASD measurements.

## MAKHTESH RAMON, THE GIANT ANTICLINAL SUMMIT VALLEY

The Makhtesh is located along the anticline axis and at its N-E part it evolved into two sub-valleys following the split of the anticline axis. It is around 40 km long, the average width is 9 km, and the depth is up to 380 meters. Makhtesh Ramon is situated at the top of the Ramon Anticline on the eastern margin of the Negev-Sinai sub-plate, overlooking the landscape channel of the local Great Rift Valley section, into which it is drained (*Fig. 51*).

The Makhtesh Ramon is a true summit valley - no alluvium flows in, as no higher zones border it (*Fig. 52*). The internal river system keeps the geological manifestations clean and well exposed - turning it into a magnificent geological window.

The Ramon anticline is well exposed, both inside and outside, providing an insight into the anatomy and evolution of the Ramon anticline, and exposing detailed information on its structure, which in turn, leads to the understanding of its evolution (*Fig. 54*). The geological map of Makhtesh Ramon (*Fig.53*) reveals a concentric structure of an outer Cenomanian ring, and in an inward direction rings of Lower Cretaceous and Jurassic, and a Triassic core. The structure discloses that the makhtesh has been excavated along the axis of an asymmetrical anticline. The Triassic - Cenomanian rock sequence is made up of conform rock strata that disclose accumulation in a flat landscape, frequented by sea invasions and retreats. In contrast, the Turonian to Eocene strata reveal angular unconformities on the outer flanks of the anticline (*marked black in Fig.54*), disclosing the initial stages of folding, during which the evolved anticline protruded as an island. When the Eocene sea retreated the whole set of the Makhteshim Country anticlines was exposed on land, where they were truncated by erosion. This truncation exposed in

some anticlines the inner core of Lower Cretaceous sandstones, but the whole region was still a low flatland and the exposed sand stone remained in place. The environment was drastically changed when the adjacent Great Rift Valley segment subsided at the Miocene and the rim of the westward moving sub-plate was uplifted, forming the present Makhteshim Country Highland. Thus, a deep drainage basin was formed and the sandstone interior of the anticline was washed away and the makhtesh summit valley was formed.

The huge summit valley of Makhtesh Ramon is full of excellent exposures of a large variety of geological features - it is a superb geology exhibition (*Fig. 55*), an ecology window, an ideal field school, and an ideal Nature Laboratory.

**1. The main road crossing the makhtesh - a trail through 230 million years of rock history.** A well designed asphalt landscape road - the main road crossing the makhtesh - is ideal for convenient geological (and other) observations, as it provides a representative cross section (*Fig. 56*). This road offers de facto a trail through 230 million years of rock history. Let us follow this road in the following brief presentation of some (out of the countless) geological peculiarities of the Ramon:

**2. The Cenomanian hard limestone walls and the Lower Cretaceous friable sandstone.** The steep upper half of the enclosing makhtesh wall is built of Cenomanian limestone, dolomite and marl beds - altogether a weathering resistant rock assemblage. Visitors are impressed by the deep fractures opened in the limestone beds, close to the rim of the makhtesh, (*Fig. 57*).

**3. The friable Lower Cretaceous sandstone.** At the lower half of the makhtesh wall is exposed the friable Lower Cretaceous sandstone (*Fig. 58*) - the rock that was so efficiently washed away when the makhtesh was sculptured. At places, fossil tree trunks are found.

**4. Alluvial pediments** depict the shape of the bottom of the makhtesh at its early powerful stage of formation. The lower part of the surrounding wall has a more gentle slope - it is built of Lower Cretaceous sandstone (Fig.58), which is largely covered by alluvial talus. Alluvial pediments stretch in the direction of the center of the makhtesh. These pediments are relicts of the early stage of the excavation of the makhtesh - when the Lower Cretaceous and Jurassic sandstone were washed out. At this early stage the makhtesh was shallower and had a nearly flat bottom. Later on, when the adjacent Rift Valley continued to subside and the landscape channel was drastically deepened, the river system cut through the harder Triassic rocks and the present narrow river bed of the Ramon River was formed.

**5. The Brown Questa (Middle Jurassic).** A brown dolomitic rock bed of the Middle Jurassic, tilted northward and seen all over the makhtesh as a brown strip. Beneath are beds of other brownish rocks - marl, silt and sandstone.

**6. The unique quartzite "Carpentry".** Let us return to the geological excursion along the main road and stop at the Carpentry. A carefully designed trail of wooden stairs passes the surrounding Jurassic sandstone and leads to a hill built of quartzitic prisms (Fig. 60). When the children of the nearby settlement of Mizpe Ramon saw these prisms they nicknamed the hill "Carpentry". The currently leading theory is that thermal fluids locally quartzized the sandstone that hardened, and upon cooling fractured and obtained the prism structure. Similar cooling prisms are common in basaltic flows and are found also at the Ramon, but quartzitic prisms seem to be unique.

**7. Jurassic sandstone and kaolinite deposits.** The Jurassic sandstone complex includes large lenses of white kaolinite, that was

quarried in the past. Plant fossils disclose a continental-lacustrine paleo-environment. The kaolinite mines have been closed and the landscape is well rehabilitated.

**8. The narrow dry river bed of Nahal (river) Ramon and the makhtesh stabilization.**

A large bridge passes over the river bed of Nahal Ramon, which is the main river of the makhtesh. A number of characteristics of the present main Makhtesh river indicate that the makhtesh is practically not growing - it is quite stabilized: (a) the river bed is a few km away from the makhtesh wall; (b) it is significantly lower than the Lower Cretaceous sandstone outcrops; (c) it is a small system of limited carrying capacity and brief floods happen on the average only once per winter. The lower sandstone slope of the makhtesh wall is at many places covered with an alluvial talus - a further indication that the makhtesh is not actively growing.

**9. Basanite flows** are exposed along the base of the NW wall of the makhtesh - they originated from the adjacent Giva't Ga'ash Volcano.

**10. Giva't Ga'ash - a 120 million years old basanite volcano (Lower Cretaceous).** From the road crossing the Makhtesh one can well see at NE a black hill, about 1 km across, 70 m high, and a valley at its center (Fig. 61). The hill, Giva't Gaa'sh (Vulcano Hill), is built of basanite - a basic volcanic rock of the basalt group, and north of it are outcrops of a brownish volcanic tuff. Thus, we are dealing with a rather well defined volcano with relicts of a crater at its center. The basanite has been dated to be around 100 to 120 million years old - in good accordance with its stratigraphic position at the Lower Cretaceous rock sequence. Westward are exposed black outcrops of basanite flows that originated at the Giva't Gaa'sh volcano. The excellent preservation of the so old volcano is explainable by quick

coverage by the Lower Cretaceous sandstone, which together with the other overlying sediments protected the volcano, which was exposed only with the opening of the Makhtesh.

**11. Active sand dunes.** At the two makhtesh NE sub-valleys visitors are surprised by the presence of windblown active sand dunes (Fig. 55), the quartz grains coming from the wide-spread Lower Cretaceous and Middle Jurassic sandstones.

**12. The Dyke Country at the east of the makhtesh - exposure of hundreds of dykes intruded into various rock beds.** From the main road branches out a well-maintained dirt road leading to the large eastern part of Makhtesh Ramon. Among the countless geological features of this region stands out a network of dykes that make up the Dyke Country (Figs 55, 62 and 63). The dykes are built of various rocks, mainly of trachyte. Their width varies from 0.2 to 3.5 m, and their length is up to a few kilometers. The uniqueness of this dyke assemblage consists in the outstanding good exposure of the bedded country rocks and the intruded dykes, as well as numerous related sills. This complex of exposed dykes is a superb research area at which a variety of dyke types is well exhibited.

**13. Kaolinitic dykes.** The above description of the dyke exposures relates to the sections intruded into Lower Jurassic rocks like dolomite, limestone, marl, shales and flintclay. A very peculiar structure is seen in the sections of these dykes that are intruded into the overlying Middle Jurassic sandstone section. At such a dyke exposure two quartzite walls, 0.2 to 1.0 m thick, protrude above the ground, and when one digs at their base he reaches whitish kaolinitic rock (Fig. 64). The formation of these specific dyke structures is still a geological enigma, but some sort of hydrothermal quartzitisation of the intruded sandstone and hydrothermal weathering of the original trachytic rock seem to have been evolved.

**14. The Jurassic flint clay (bauxite) and lateritic paleo-soil.** At the base of the Jurassic rocks of Makhtesh Ramon occurs flint clay. The term is applied for a whitish rock composed of oxides of silicon and aluminium, similar to bauxite. With it occurs a lateritic rock - reddish, composed mainly of iron oxide. Such rock assemblages represent a paleo-soil formed at a tropical environment. This discloses that at the Lower Jurassic the sub-plate was close to the equator.

**15. The Upper Triassic gypsum landscape.** The Triassic rock sequence exposed at the makhtesh includes an upper unit of about 150 meters of gypsum with thin interlayers of dark shales, limestone and dolomite (Figs. 55 and 65). This is a rather rare opportunity for visitors to stroll around in a bright landscape of gypsum hills. The gypsum was quarried for the cement industry, but this was stopped and the area was successfully rehabilitated ([section 2d.'Integrity'](#)).

**16. The laccolith - a rare exposure of the entire intrusive body.** At the center of the makhtesh, east of the main road, extends a black igneous body, intruded into the white gypsum strata. This is a mushroom-shaped laccolith, built of 130 million years old porphyritic essexite. It is 3 km long, 50 m thick at its center, and less than 10 m at its margins. The laccolith that intruded the gypsum layers is like them tilted NW and the erosion exposed a complete cross section (Figs. 55 and 66).

**17. Har Gevanim - the fossils-rich Triassic rocks.** The Triassic rocks exposed at Makhtesh Ramon are rich in fossils, including picturesque ammonites (Fig. 67). An impressive number of publications dealing with the fossils is included in the sorted bibliography ([section 7e.](#)).

**18. The Gavnunim intrusive bosses.** Half a dozen nordmarkite bosses, tens of meters in diameter, are exposed within the lowest Triassic rocks (Fig. 55). The intrusive contacts are easily observable,

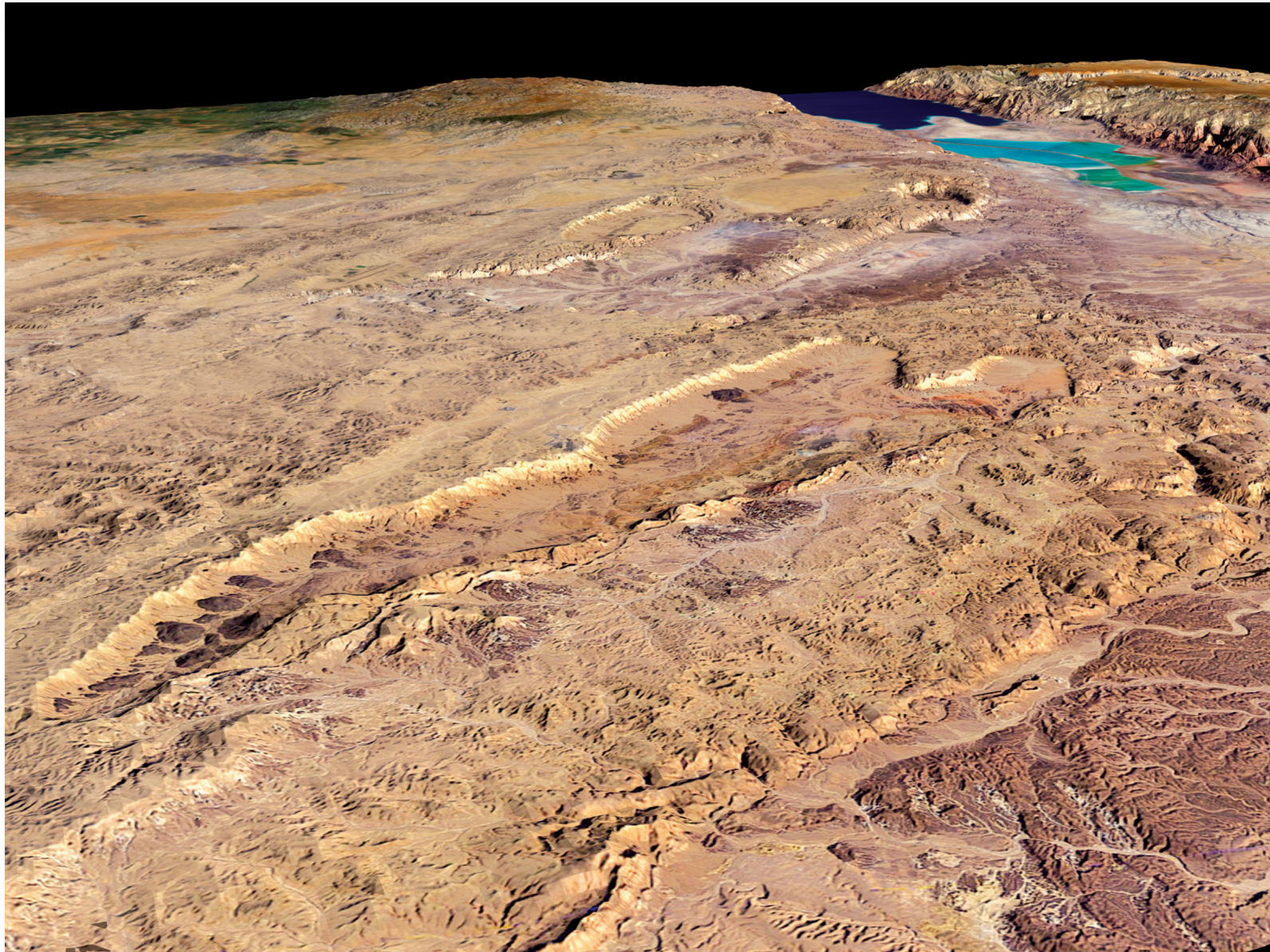
and they are decorated by colored strips of metallic mineralization - the product of hydrothermal activity.

**19. The Shen Ramon igneous stock.** Near the center of the SE rim of the Makhtesh protrudes a 100 m high igneous nordmarkite stock of Upper Jurassic, 1600 m long and 750 m wide (*Fig. 68*).

**20. The Ramon tectonic lineament.** The Ramon anticline is bounded along its SE flank by a complex regional fault system (*Fig. 55*), which drew the attention of many researchers.

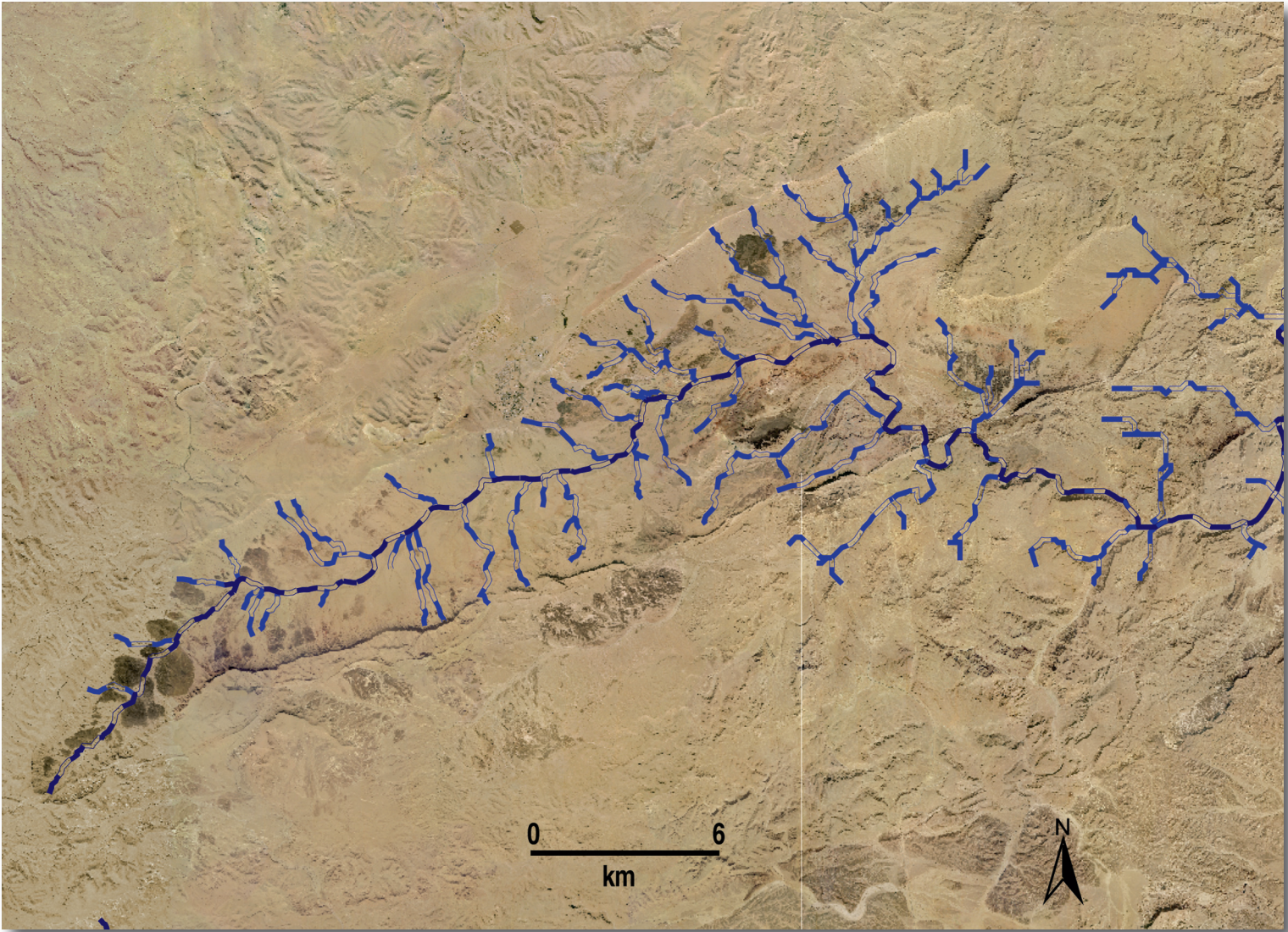
**21. The Karney Ramon volcanic basanite complex (Lower Cretaceous) at the west of the Makhtesh - a hot spot event?! A** much larger basanite volcanic complex of the same age as Giv'at Ga'ash is well exposed at the SW section of Makhtesh Ramon. This is the Karney Ramon (Horns of Ramon) complex (*Figs. 55 and 69*). Mt. Arod is the largest structure, 250 m above the Ramon River bed, and of a diameter of around 800 m at its base. The lower part is built of different volcanic rocks and at the upper part is a frozen lava lake. In addition, the Karney Ramon complex includes volcanoes; up to 13 lava flows; tuff accumulations; phreatic explosion pipes and dykes. Xenoliths found in the basanitic rocks indicate a deep origin of the lava - from the upper mantle. The Giva't Gaa'sh and Karney Ramon basanitic complex discloses a brief and intensive volcanic episode, possibly indicating that the respective continental plate passed at the Lower Cretaceous above a hot spot.

**Fig. 51:** A 3D montage of Makhtesh Ramon and the other makhteshim, located on the highland edge above the Arava River segment of the great Rift Valley (Hatzav and Mazor)





**Fig. 52:** The river system of Makhtesh Ramon (thick blue lines) - another example of a perfect summit valley marked on a satellite image (Yitzhak + Mazor)



LEGEND		
Symbol	Geology	
q	Alluvium	Quaternary
qs	Sand Dunes	Quaternary
ls	Landslide	Quaternary
nqc	Conglomerate units undifferentiated	Quaternary
m	Hazeva Fm.	Miocene
ue	Qeziot Fm.	Upper Eocene
eav	Avedat Group.	Lower-Middle Eocene
enm	Nizzana, Horsha, Matred fms.	Lower-Middle Eocene
mp	Ghareb and Taqiye fms.	Miocene
ca	Mishash Fm.	Campanian
sc	Menuha Fm.	Coniacian-Campanian
con	Zihor Fm.	Coniacian
t	Ora and Gerofit fms.	Turonian
c3	Tamar Fm.	Cenomanian
c2	En Yorqe'am, Zafit and Avnon fms.	Cenomanian
c1	Hebyon F.	Albian-Cenomanian
lck	Kurnub Group	Lower Cretaceous
im	Intrusions and volcanoclastic rocks	Mesozoic
βlc	Basalt flows	Lower Cretaceous
jm	Mahmal, Zohar and Matmor fms.	Middle Jurassic
jle	Inamr Fm.	Lower Jurassic
jli	Mishhor and Ardon fms.	Lower Jurassic
tr3	Mohilla Fm.	Upper Triassic
tr2	Saharonim Fm.	Middle Triassic
tr1	Gevanim Fm.	Lower Triassic

**Fig. 53:** Geological map of Makhtesh Ramon (Geological Survey of Israel, 1998), with the Makhtesh drainage system (Yitzhak)

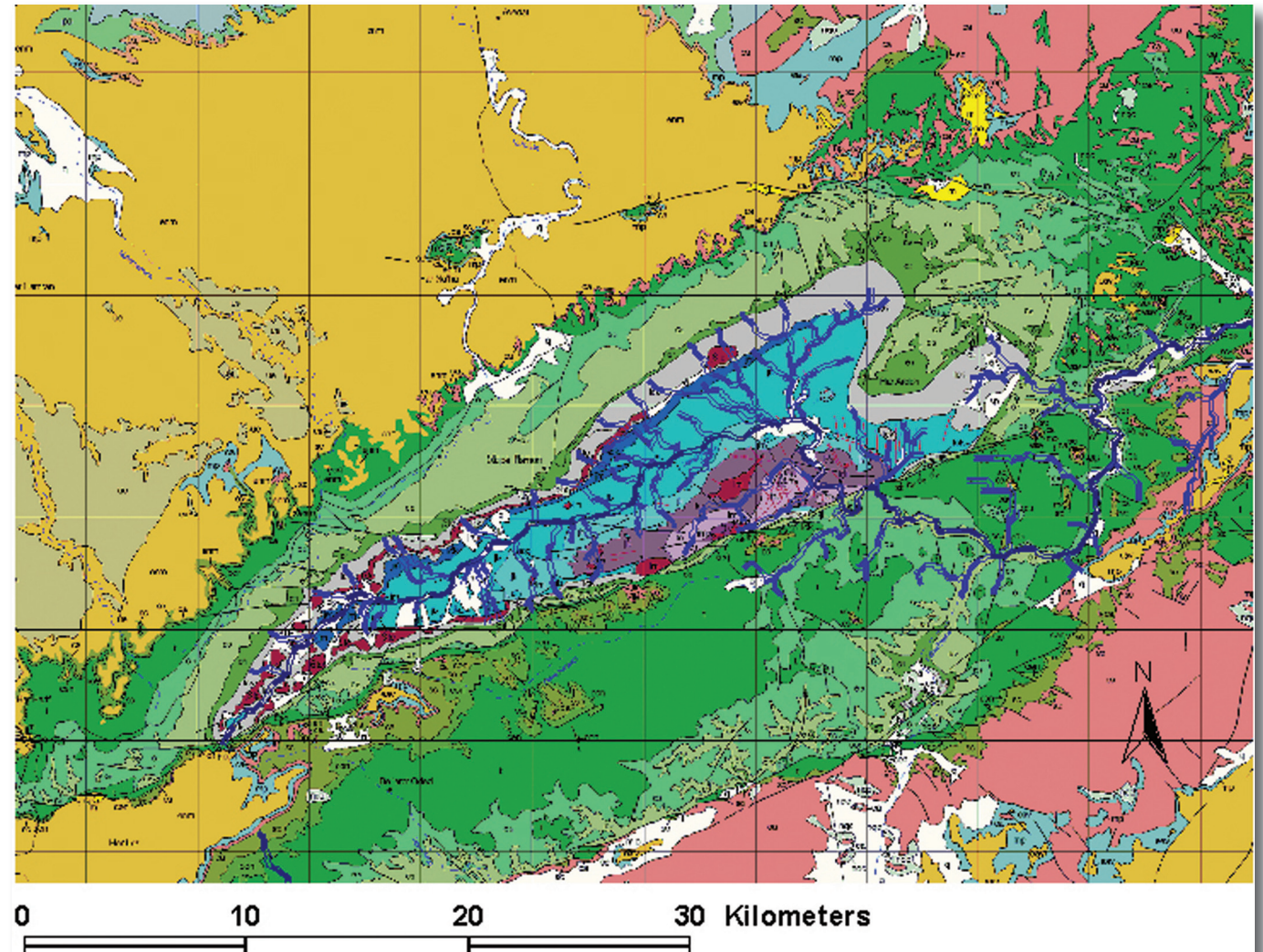
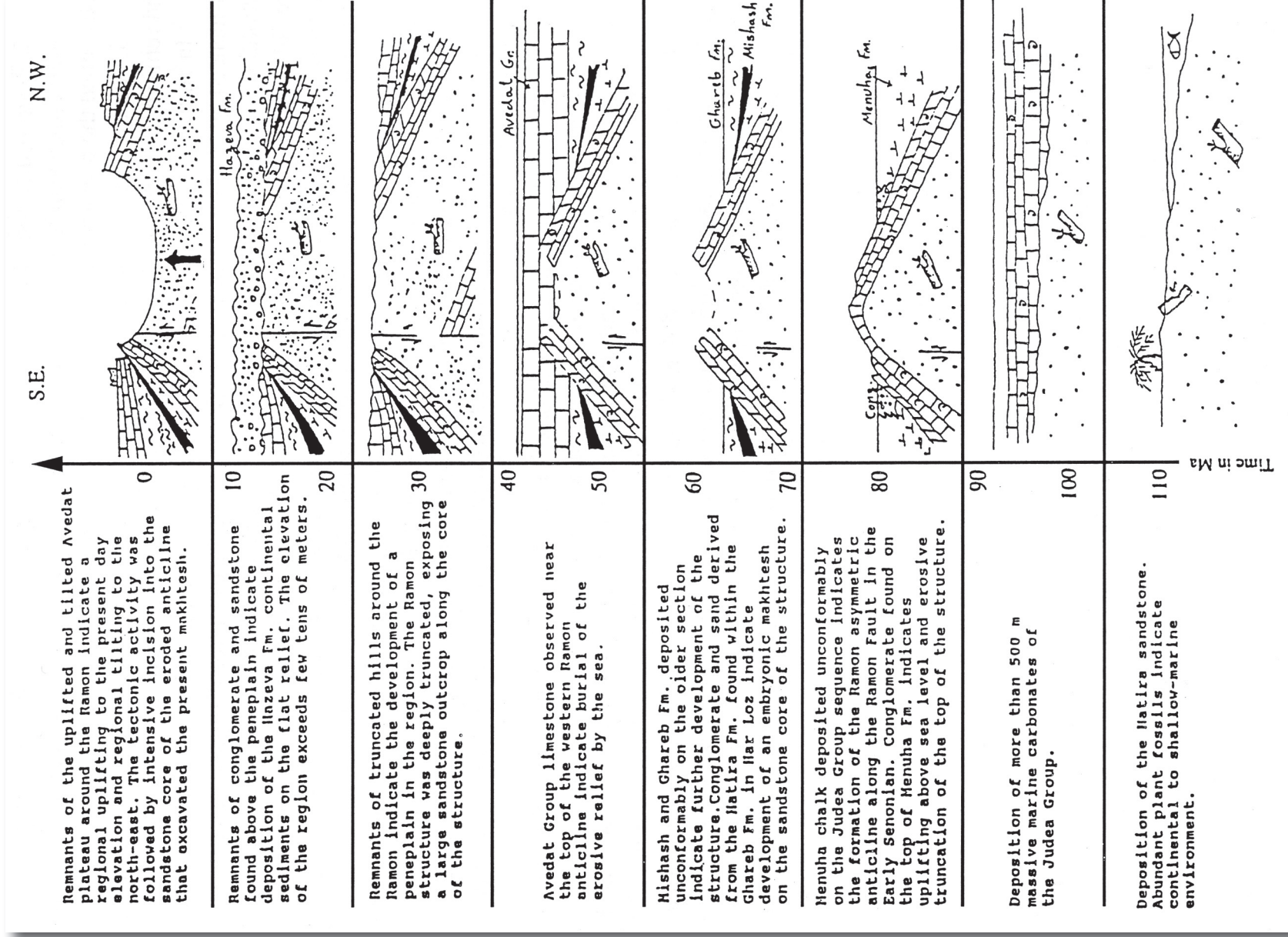
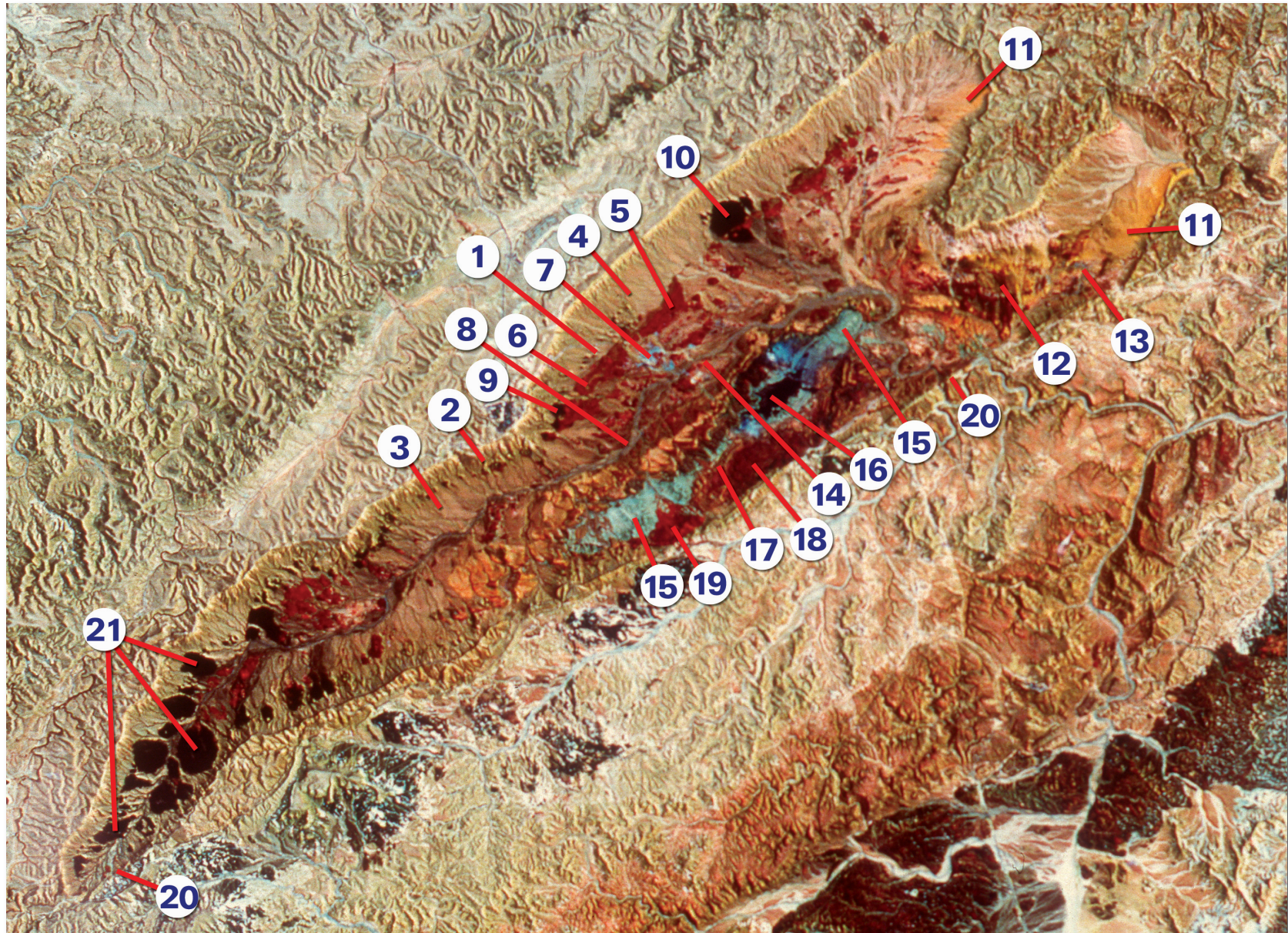


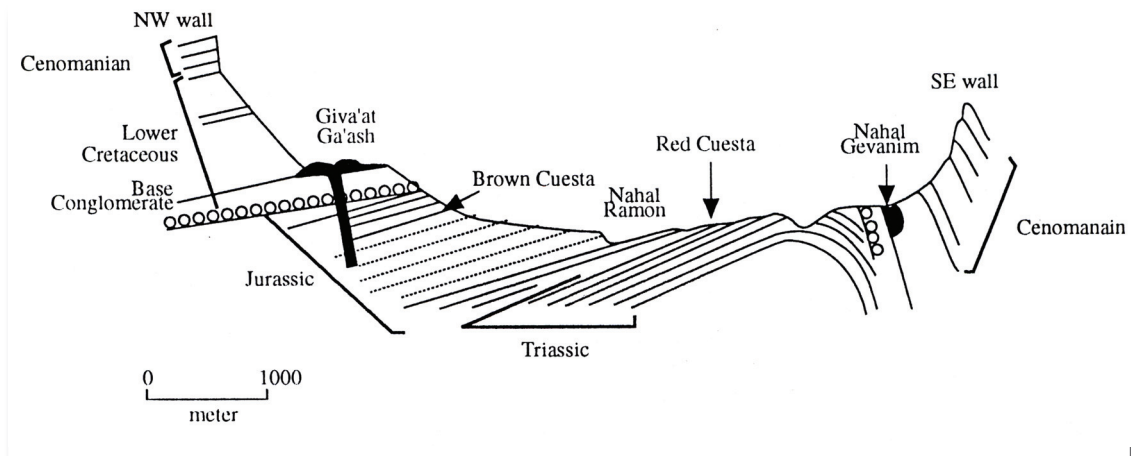
Fig. 54: Inferred stages of the evolution of the Ramon anticline and the carving out of the makhtesh (Avny, 2001).



**Fig. 55:** The geological window of Makhtesh Ramon - a satellite image (Kaufmann, LANDSAT-5 data). The numbers mark an assortment of the countless geological phenomena that are discussed in the previous sections.



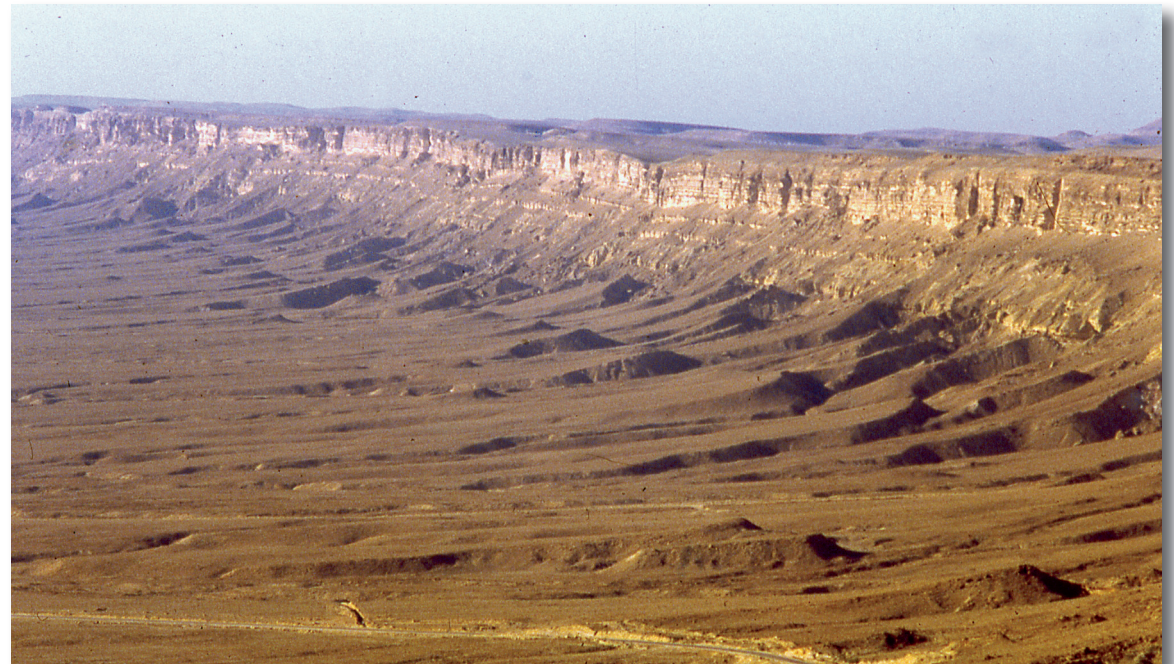
**Fig. 56:** A geological cross section through Makhtesh Ramon, parallel to the main road that crosses the makhtesh (Mazor)



**Fig. 57:** Dramatic cracks at the limestone beds at the rim of Makhtesh Ramon, near the Visitors Center (Mazor)



**Fig. 58:** Lower Cretaceous sandstone at the lower part of the NW wall of Makhtesh Ramon (Mazor)



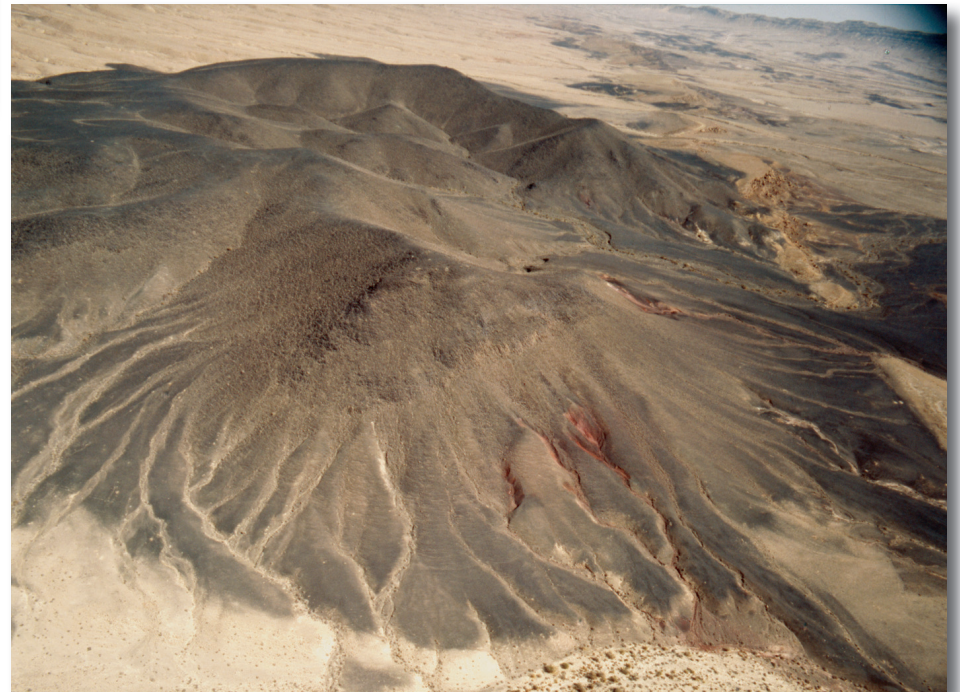
**Fig. 59:** The NW wall of Makhtesh Ramon: it is steep at its upper part (mainly limestone and dolomite) and has a more gentle slope at its lower part (mainly sand stone). Alluvial pediments are relicts that depict the flat bottom of the Makhtesh at the early stage of its formation (Mazor)

**Fig. 60:** Close-up of the Carpentry quartzite prisms (Mazor)



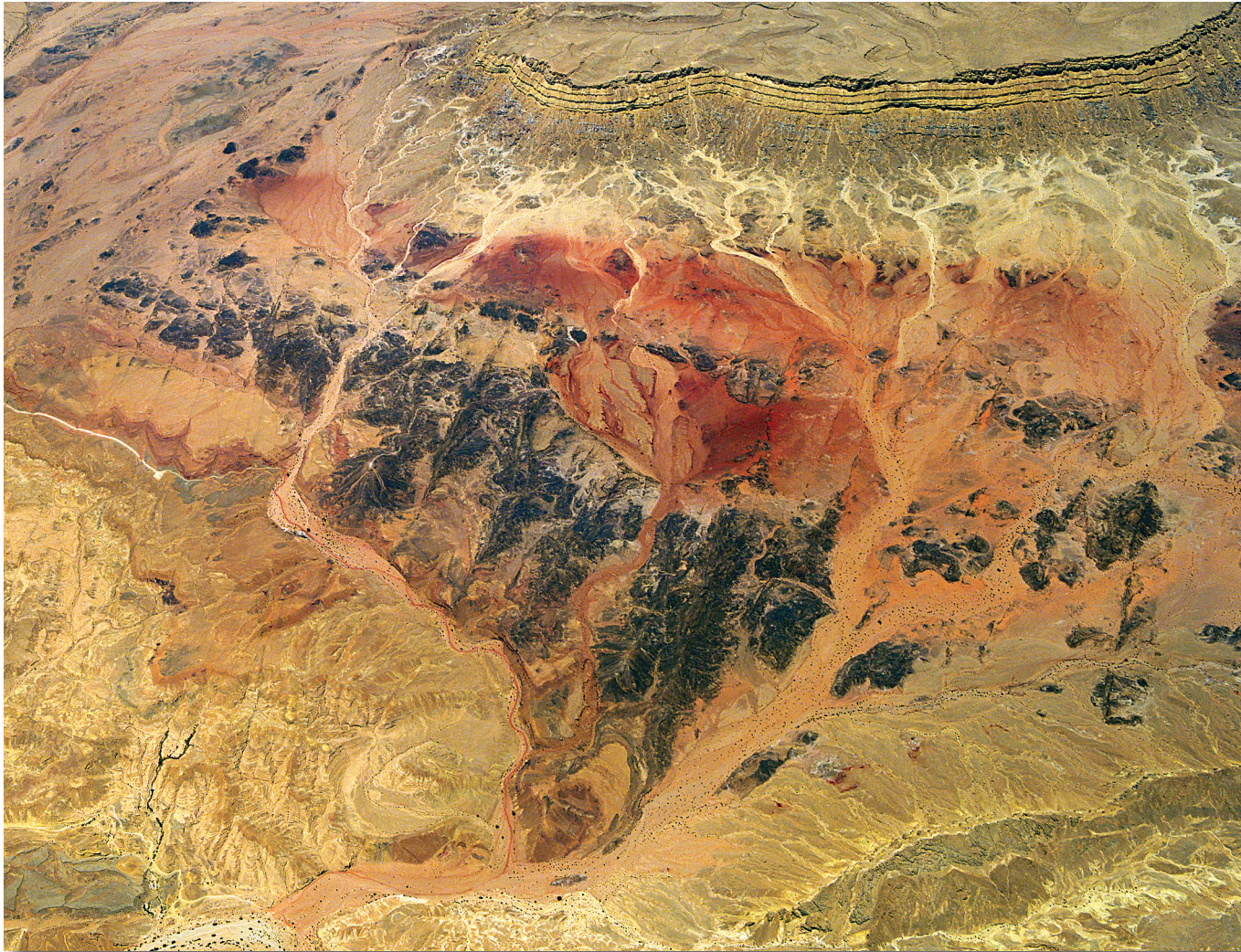


**Fig. 61:** Giva't Gaa'sh - a well preserved Lower Cretaceous basanite volcano (Engelstein)





**Fig. 62:** Air photo of dykes at the eastern part of Makhtesh Ramon (Hatzav, Ofek)



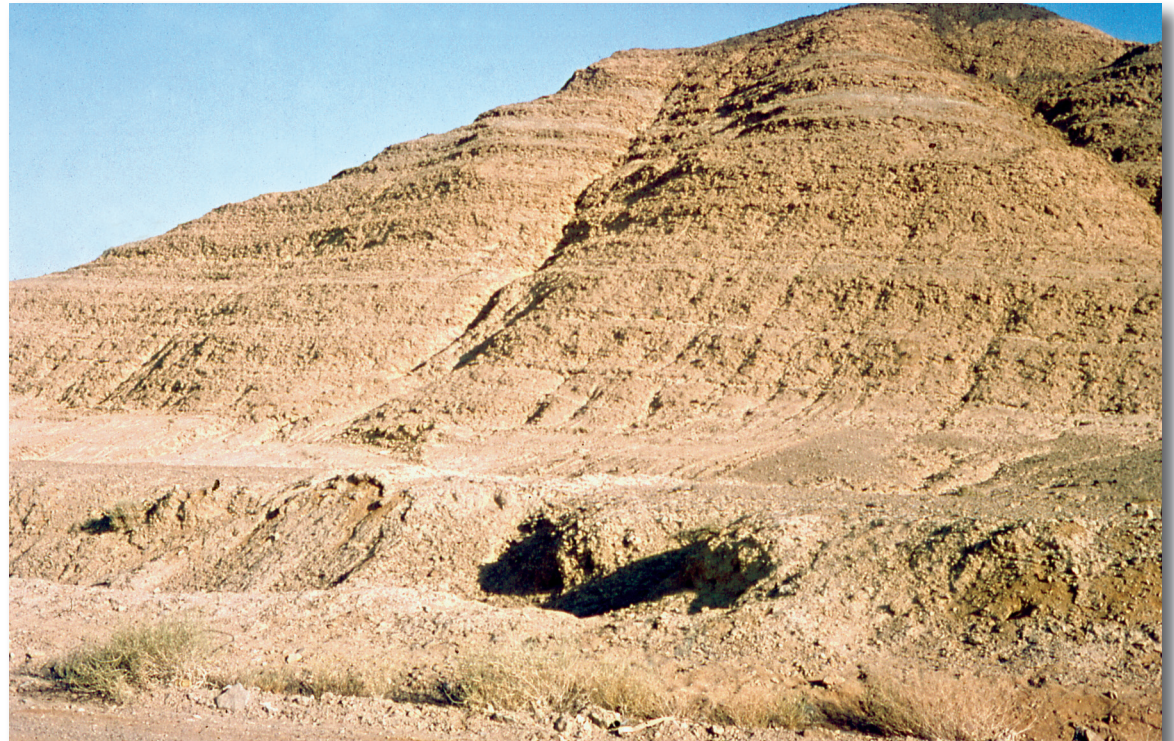
**Fig. 63:** Close-up of a dyke intruded into well-bedded Lower Jurassic rocks, Makhtesh Ramon (Mazor)



**Fig. 64:** A 'kaolinitic dyke': A photo revealing the two quartzitic walls and a pit dug into the kaolinized dyke - a sight common in the two NE sub-valleys of Makhtesh Ramon (Mazor).



**Fig. 65:** Bare gypsum (Triassic) hills at Makhtesh Ramon (Mazor)



**Fig. 66:** Air photo of the laccolith, revealing rocks of different kinds of dark colour - revealing several stages of magma intrusions. The laccolith intruded into the whitish gypsum Triassic rocks. (Engelstein)



**Fig. 67:** A Triassic ammonite,  
Makhtesh Ramon (Mazor)



**Fig. 68:** Oblique air photo of the Shen Ramon nordmarkite stock (center); the southern wall of the Makhtesh (left) and white region of Triassic gypsum (top center) (Engelstein).



**Fig. 69:** Oblique air photo of the Karney Ramon volcanic complex, at the western edge of the makhtesh (Engelstein)

