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Gypsum karst near Sivas, Turkey

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Abstract: A large area of spectacular karst stands on thick Miocene gypsum in central Turkey. Numerous dolines coalesce into fine polygonal karst. Large collapse dolines and marginal poljes are also notable features. Few caves are known, but some sinkholes, stream passages and foot caves await complete exploration.

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TERRAIN

Massive gypsum extends across two large areas of outcrop in central Turkey (Fig.1), and has been eroded into some very fine karst landscapes. Though no long caves are yet known, there are some large collapse features and spectacular stretches of polygonal karst. The area around Sivas appears to constitute a gypsum karst terrain of exceptional quality in terms of its numerous, extensive and well-developed landforms.

Both the karst and the caves are very poorly documented. A number of caves in a small part of the karst east of Sivas were investigated by Mayer (1974), but he was in the field only briefly and did not have the time for thorough exploration. A few papers (cited below) describe individual aspects of the hydrology (Gunay, 2002) or geomorphology of parts of the karst. A longer thesis by Alagoz (1967) is written in Turkish, with a long abstract in French, but is not widely available. It documents many of the karstic surface features in the Kizilirmak valley between Sivas and Imranli, but has almost no data on caves. The writer's observations in the Sivas area derive from four brief visits (spread over 30 years), and this short review is intended to draw attention to a truly splendid gypsum karst that warrants further exploration and research.

The karst is an open rolling landscape with hills that are a mix of bare gypsum outcrop with grassland on thin soils (Fig.2). Alluviated basins and valley floors are cultivated, mainly for grain. Hills reach to altitudes of about 1500m, but local relief within the karsts is less than 300m. The interior climate has a low rainfall (around 400mm), with summers that are hot and dry, modest autumn rains, and light snow cover through cold winters. The area is very accessible for those with their own transport. Sivas is a regional centre, and Zara is a lively, small market town. The karst is crossed by the main Europe-Asia highway between Ankara and Erzerum, while a few small roads and a dense network of dirt tracks spread just about everywhere.

GEOLOGY

Miocene gypsum of the Hafik Formation reaches to thickness of 750m, but this includes a significant proportion of interbedded clays, and the greatest thicknesses may reflect some squeezing into diapiric structures. The structure of the gypsum is extremely complex as it is trapped in a compression belt between the Anatolian block and the mountain belt that fringes the Black Sea. Bedding is recognisable only locally, but east-west folds form the main structures. Much of the gypsum is fine-grained and massive, though there is extensive recrystalisation with blades of clear selenite over 200mm long. Some zones of the gypsum are heavily brecciated; domes and diapiric structures may be interpreted, though there is room for debate over these, and the presence or scale of any deep-seated breccia pipes also remains unknown.

Clastic rocks form the sequences both above and below the gypsum. Eocene sandstones form the anticlinal mountain ridge of the Gurlevik Dag, on the watershed between the Black Sea and the Arabian Gulf. Alluvium is extensive along the floors of the major valleys, on which all the main rivers maintain surface courses across the gypsum. Outcrops of

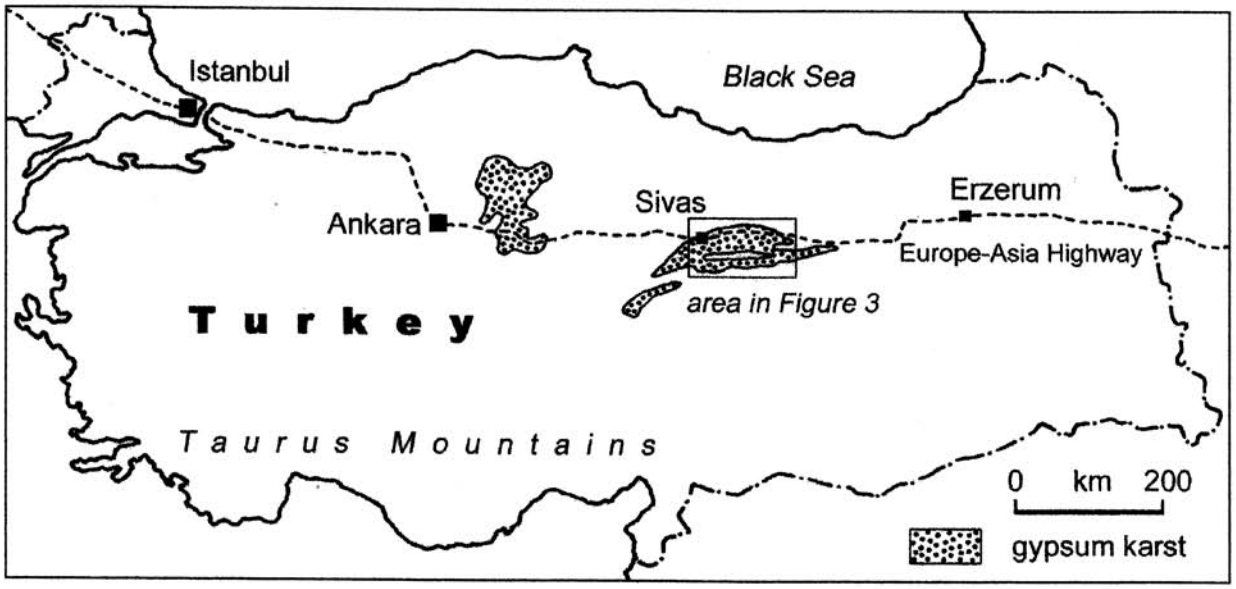

Figure 1. The main outcrops of Miocene gypsum in central Turkey.

Figure 2. Gypsum hills of the Sivas karst, south of Hafik.

the gypsum range from rounded hills of bare white rock on the more massive material, to rolling slopes and basins covered with thick clay soils that are at least in part dissolution residues. At outcrop there are no signs of anhydrite, which has been seen in boreholes at depth.

DOLINE KARST

A belt of high ground on the gypsum extends from Sivas east to Imranli. The Kizilirmak River cuts through its eastern end and then flows largely along its northern margin (Figs 3 and 4), whereas the Acisu River drains through a fine rocky canyon that is entrenched 150m below the karst plateau. The plateau surface is eroded into broad dolines that coalesce into shallow dry valleys where the overall slopes are steeper. There is enough clay interbedded with the gypsum to provide residual soils that are nearly continuous, with thicknesses of 1 to 5m across most of the karst. Small subsidence dolines are common within the soil cover, and many show signs of recent collapse (probably during wet weather).

Over much of the plateau a polygonal net of low interfluve ridges encloses shallow depressions with internal drainage into small sinks. Many individual basins are poorly defined and are 1 to 3km across, but some areas have smaller dolines within a tighter net, as in the area southeast of Demiryurt (Fig.4). The best of this polygonal terrain is immediately west of Imranli (Fig.3), where it constitutes a truly outstanding karst landscape (Fig.5). Dolines occur at densities of 80 to 100 per km^2. Each is 100 to 200m in diameter, with a soil floor about 50m across (cultivated and therefore largely flattened) below gentle slopes of bare gypsum and patchy soil rising 10 to 20m to the inter-doline ridge (Fig.6).

This polygonal karst creates a spectacular landscape. It occurs in all stages of development, recognisable by dolines increasing in size and decreasing in number. The Imranli karst appears to be the most youthful. An extensive area southwest of Sivas has well defined polygonal basins but their density is only about 10 per km^2. South of Zara and Hafik, an older landscape has poorly defined basins, each of which extends to more than 1km^2.

Most rainfall sinks directly into the gypsum outcrops or their soil cover, but some collects on the doline floors and feeds into small sinkholes. On steeper overall slopes, some sinking streams resurge in the next doline, but most drainage is lost to deep circulation. Most of the groundwater appears to resurge into the beds of lakes and rivers that lie within the karst. Along the northern margin of the karst, Todurge Golu is just the largest of a number of lakes that have significant outflows but little or no visible inflow. Small risings are scattered through the karst, and most of them feed villages or farms. Just northeast of Sivas, the Seyfe and Goydun springs (Fig.4) have mean discharges of 0.25 and 1.15m^3/s respectively. These are significantly large karstic risings that have notably constant flows fed from extensive underground basins (Kacaroglu *et al.*, 1997).

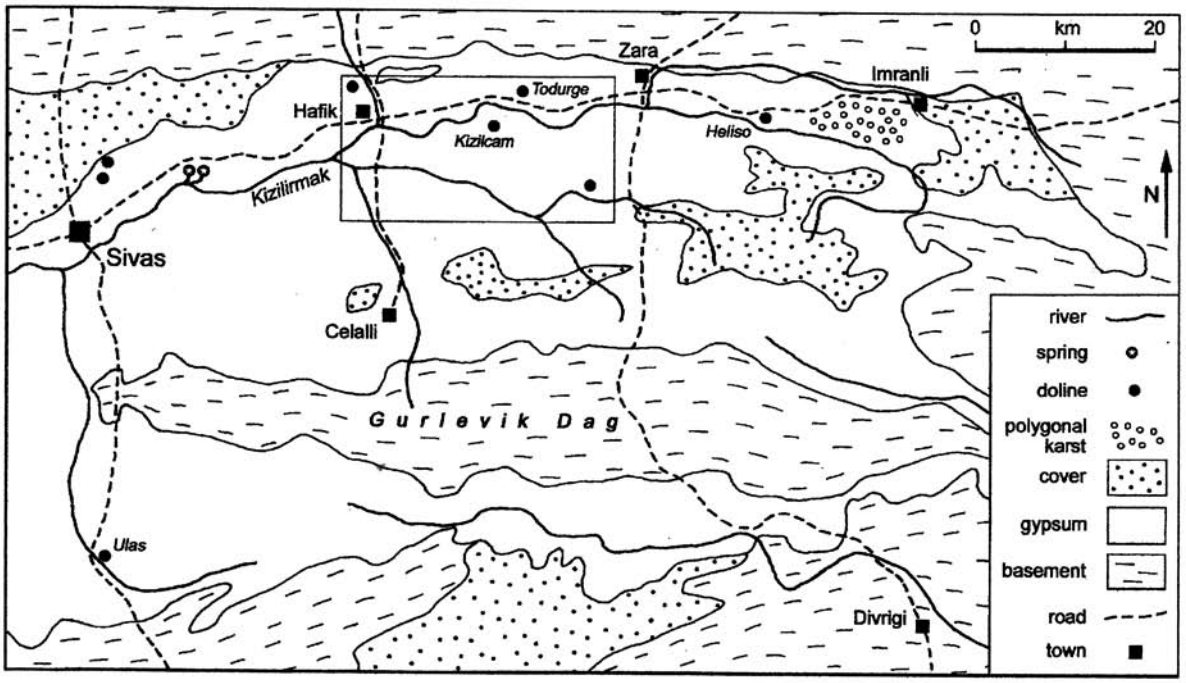

Figure 3. The extent of the gypsum karst east of Sivas. The basement comprises Jurassic to Eocene clastic rocks and the cover consists of various late Tertiary clastic sediments, some of which are interbedded with the gypsum. Alluvium (not shown) lies along the lower parts of the main river valleys. The only dolines marked are the larger collapse features. The area of this map is identified on Figure 1, and the boxed area east of Hafik is shown in Figure 4.

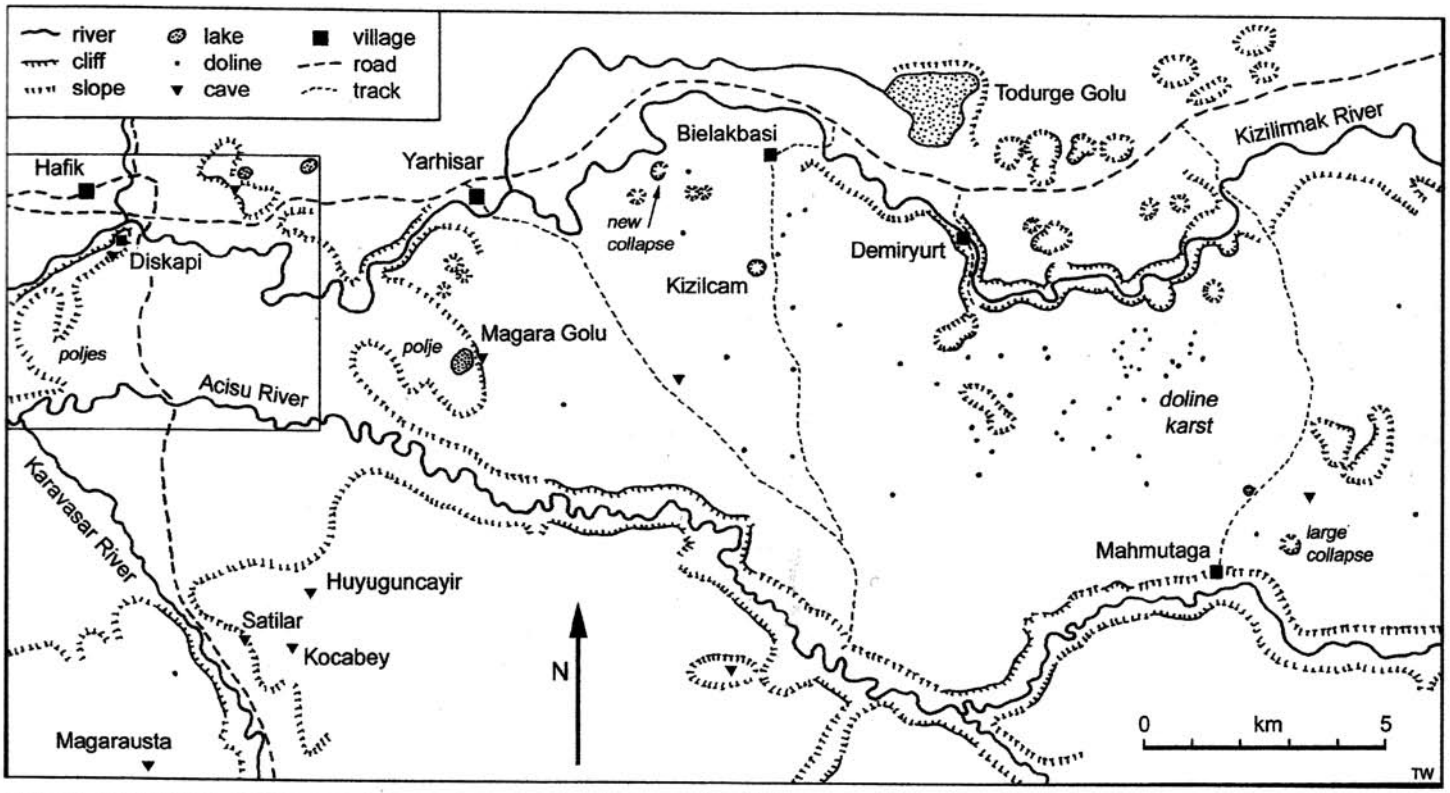

Figure 4. Some features of the geomorphology in the gypsum karst just east of Hafik. The area of this map is identified on Figure 3, and the boxed area around Diskapi is shown in Figure 10.

COLLAPSE DOLINES

The Sivas gypsum karst is distinguished by a number of large collapse features. These are scattered right across the areas of more mature karst, and they appear to be generally lacking in the more youthful polygonal karst. The finest single landform is the Kizilcam doline, east of Hafik (Fig.4). It contains a lake 220m in diameter surrounded by steep rock slopes that rise 30 to 50m to a rim about 350m in diameter (Fig.7). The doline breaks a gently graded gypsum surface that descends from the rim of the Acisu canyon northwards to the Kizilirmak River (which is not entrenched west of Bielakbasi village). The lake surface is at the same level as the latter river, 3km away. The depth of sediment or breakdown material below the lake is unknown. Kizilcam is a textbook collapse doline, except that its sides are now degrading so that it has already matured into a well-rounded shape.

The scale of the collapse event or events that formed the Kizilcam doline is open to debate, but may be indicated by processes in an active collapse doline that lies close to the Kizilirmak River, 2km west of Bielakbasi (Fig.7). This feature is about 200m across, floored partly by a chaos of breakdown blocks; it also has a small lake, ponded to the level of the adjacent river, only 10m below the surrounding terrain. The north wall of the doline is a cascade of gypsum blocks each about 4m across. The south wall has larger blocks of gypsum that appear to have dropped into a cave perhaps 25m across (Fig.8). The processes of dissolution, undercutting and block collapse are clearly active, with dissolution mainly at the water table level. The scale of breakdown suggests that the larger old collapse dolines (including Kizilcam) evolved by a long sequence of progressive breakdown failures. Few stable cave chambers in gypsum caves elsewhere in the world are more than 40m across, and this is commensurate with the size of cavity growth and collapse seen to be occurring in the Sivas gypsum.

Figure 5. Polygonal karst south of Imranli.

Figure 6. Dark ploughed soils on doline floors in the polygonal karst west of Imranli.

There is a group of large collapse dolines on the karst plateau near the village of Mahmutaga (Fig.4). The finest is a rocky bowl 400m in diameter, with a nearly flat floor 40m below the plateau surface (Fig.9), and over 100m above the Acisu River, just to the south. This appears to be a very old feature. Its original floor was probably within the zone of maximum dissolution at river level, prior to considerable entrenchment of the Acisu. It is also degraded and rounded, and its grassy floor may mask a considerable amount of breakdown debris, though Alagoz (1967) reports a temporary lake on its floor. Just to its northeast, two even larger basins, each nearly a kilometre across, appear to be even older collapse features, now alluviated, more degraded and perhaps coalesced from smaller original features; they also contain shallow temporary lakes. A smaller and younger collapse doline, beside the track to Mabanir, has a vertical wall on its down-dip (southeast) side, where it is still being undercut by dissolution as water drains down the gypsum bedding.

A very accessible collapse doline is Heliso Cukuru, beside the main road between Zara and Imranli. It is over 300m across and 50m deep, though it is old and degraded. Large collapse dolines just northeast of Sivas were noted by Karacan and Yilmaz (1997), and the Ulas lake appears to lie in another (Fig.3). The Kizilirmak River appears to have incorporated some collapse dolines during entrenchment of its gorge upstream of the village of Demiryurt. Two features in the south wall of the gorge, 4 and 5km east of Demiryurt, resemble cut-off incised meanders (Fig.4). However, they lie within a zone of collapse dolines of comparable size, and the gorge breaches the edge of another large doline (that is clearly not a cut-off meander) 1km south of Demiryurt. The implication may be that much of this gorge was excavated by serial cave development, collapse and unroofing.

POLJES AND BASINS OF THE KARST MARGIN

The largest dissolution landforms on the gypsum appear to lie along the northern margin of the karst. Todurge Golu is a shallow lake in a large karstic basin (Gunay, 2002) at the western end of a zone of massive dolines and collapse features (Fig.4). These all lie at the current base level, where dissolution along the trunk drainage routes appears to be undercutting and widening the dolines, until they coalesce into broader and degraded basins. Hafik Golu, just north of the town, is another lake of similar origin.

The next stage in the karstic surface lowering may be represented by alluviated basins on and along the courses of the trunk rivers. These are best seen south of Hafik, where the Kizilirmak and Acisu rivers emerge from the karst plateau and their valleys are separated only by lower gypsum ridges (Fig.10). Both rivers meander across alluviated floodplains and undercut the marginal gypsum slopes wherever they reach them. The base-level undercutting and collapse of the cliff west of Diskapi village is on a spectacular scale; one tilted block 100m long is now separated from the cliff by a box canyon formed by a combination of mass movement, cave unroofing and massive blockfall. Drainage from the small lake of Lota Golu passes through a gypsum ridge in a cave that has now almost completely collapsed to create a narrow gorge.

Between the two large rivers, two poljes drain entirely underground (Fig.10), and have the characteristic flat floors with eroded toes on their marginal slopes. These basins may once have been occupied by meander loops of either river, or they may be true poljes that evolved from features like those now active at and east of Todurge Golu.

Figure 7. The spectacular collapse doline of Kizilcam, with scale given by a person standing on the rim to the right.

Figure 8. A corner of the active collapse doline east of Bielakbasi, with large and small fallen blocks of gypsum undermined by dissolution.

Subsidence troughs (elongate dolines formed over linear zones of rockhead dissolution) are recorded near Sivas (Kacaroglu *et al.*, 1997), but none has been recognised in the Hafik area.

CAVES

Though the Sivas gypsum karst is clearly cavernous, there are very few recorded or fully explored caves. The geological structure precludes development of long maze caves comparable to those in the Ukraine, and there are no cave chambers (yet known) to match the scale of the collapses that have formed the large dolines. Most of the known caves lie around Hafik.

The ridge straddled by Diskapi village has a variety of caves well worth further investigation (Fig.10). Near the top of the hill north of the village, there are at least two entrances (beside that to a large artificial tunnel). Both caves are dry systems of rifts and fissures, with signs of both landslip opening and dissolutional enlargement. Passages 1m wide and 5m high extend up and down various climbs and continue beyond the limits of the writer's hurried explorations. An impressive entrance (Fig.11) that clearly takes water under wet conditions flanks the polje south of the village. Inside, this spacious passage soon splits into a series of tubes that are partly choked by mud and flood debris, and only 100m of passages are easily reached. It is a classic foot cave cut cleanly across the steeply dipping gypsum beds. Passages must continue through the hill, though they may be too small or too choked for access. There are at least three cave entrances in the collapsing cliff on the northwestern side of the ridge. The western cave has an old series of dry and dusty rifts and chambers ending in chokes. The middle entrance is a water-table dissolution slot at the foot of the cliff; it requires a little digging and grovelling to enter, but a strong emerging wind suggests a link with caves higher within the hill. The eastern cave has an entrance 4m in diameter truncated 15m up the cliff face behind the main landslip block, but the villagers know a way in from another entrance.

East of Hafik, Lota Golu (Fig.10) drains into the breakdown that floors a collapse gorge through the gypsum ridge, where the only surviving cave is a passage fragment less than 50m long (Mayer, 1973). Several other partially collapsed caves, one with a chamber 30m across, are reported by Mayer (1974), with no reference to their exact locations. A cave entrance 15m high and 20m wide breaks the cliff beside Magara Golu (Cave Lake) (Fig.4). The large passage is only open for 40m to a breakdown pile below a collapse skylight (Mayer, 1973), though the cave takes overflow water from the lake, and smaller passages do continue.

Numerous cave entrances can be seen from the main road east from Sivas, and some look worthy of further investigation. The caves of Kaya Magaralar are sign-posted from the road between Hafik and Zara, and consist of a large number of natural entrances truncated in the cliff above the village of Demiryurt (Fig.4). Some have been enlarged artificially, probably to serve as hermitages, and whether any continue farther back into the hill is unknown.

The longest recorded caves were explored by Mayer (1973) in the gypsum hills south of Hafik. Kocabey Cave has a small stream passage that can be followed for 300m to a series of descending chambers where the water is lost into a narrow fissure. It is probably the same water that emerges from Satirlar Cave, 1000m to the west and 100m lower down (Fig.4). Another 300m of passage can be followed upstream before it becomes rather low (Mayer, 1973, 1974). This stream drains off a soil-covered outcrop of impure gypsum, but there are no known sinks where

Figure 9. The large degraded collapse doline east of Mahmutaga.

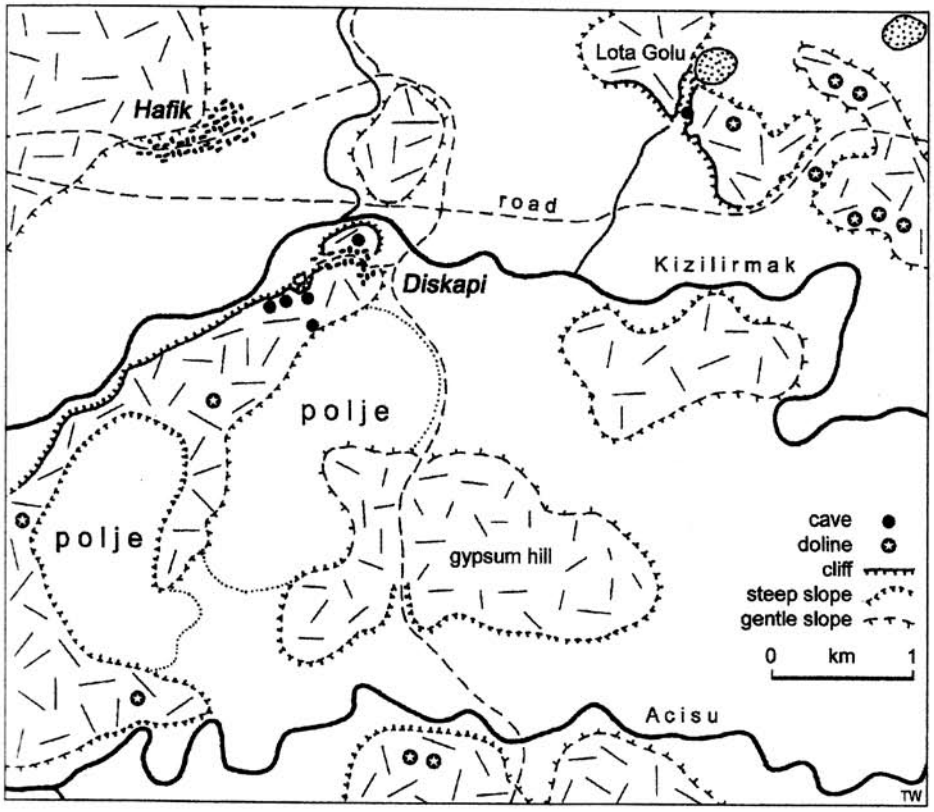

Figure 10. Poljes and caves around Diskapi, just south of Hafik. The area of this map is identified on Figure 4.

streams drain onto the gypsum from larger catchments on adjacent clastic rocks. Huyuguncayir Cave has a stream draining through three collapse chambers 10 to 15m across, and Magarausta Cave has at least 150m of small stream passages between a line of collapse entrances. These were both recorded by Mayer (1973), along with many other shorter caves in the hills towards Celalli.

The doline and polygonal karst areas farther east have many small sinks on the edges of the sediment floors in the depressions. Many are choked or narrow but some may reveal open cave passages after a little clearance. One open sink lies in the large doline south of the Acisu canyon (Fig.4). A short blind valley, cut 15m deep through the sediment fill, drains into a steep passage in cleanly washed gypsum. This narrows to a partial mud choke after only 20m, but the passage continues for a visitor prepared to contort gently, perhaps excavate a little, or hit lucky after a convenient flood. There is undoubtedly much more to be revealed in the splendid gypsum karst of Sivas.

REFERENCES

Alagoz, C A, 1967. Sivas cevresi ve dogusunda jips karsti olaylari (Gypsum karst around and east of Sivas). Ankara *University Faculty of Geography Thesis*, 175, 126pp.

Gunay, G, 2002. Gypsum karst, Sivas, Turkey. *Environmental Geology*, Vol.42, 387-398.

Kacaroglu, F, Degirmenci, M and Cerit, O, 1997. Karstification in Miocene gypsum: an example from Sivas, Turkey. *Environmental Geology*, Vol.30, 88-97.

Karacan, E and Yilmaz, I, 1997. Collapse dolines in Miocene gypsum: an example from Sivas (Turkey). *Environmental Geology*, Vol.29, 263-266.

Mayer, D V, 1973. *A list of some of the caves and swallow holes in the gypsum karst between Sivas and Zara, Turkey*. Unpublished notes, BCRA Library, 7pp.

Mayer, D V, 1974. Gypsum caves in Turkey. *BCRA Bulletin*, No.3, 15-16.

Figure 11. The entrance to the foot cave in the Diskapi gypsum ridge, on the north side of the adjacent polje.