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KARST GEOMORPHOLOGY AND HYDROLOGY OF THE DINAR AREA, TURKEY

by

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ABSTRACT

The headwaters of the Büyük Menderes Nehri river are supplied by springs during the dry season, any rainfall moving directly underground. The springs are supplemented by surface flows during periods of heavy rainfall in the winter months when the ephemeral drainage channels become active. The resurgences are of two types:

(*a*)Those fed by percolation waters from a very fractured and often thinly bedded area of limestone.

(*b*)The one at Işikli fed by the surface river sinking gradually into its bed, plus water stored in alluvial floodplains and transmitted to the resurgence by a well-fractured aquifer in which a master conduit may have developed.

During the summer of 1986 seven members of the University of Bristol Spelaeological Society and two of the Westminster Speleological Group went to the Western Taurus mountains, Turkey, with the intention of locating and exploring caves in two separate areas. The first of these, previously unvisited by speleologists, lies between and to the north of the towns of Dinar and Çivril in the Afyon and Denizli provinces of Turkey some 690 km south-east of Istanbul and 145 km north of Antalya (Figs. 1 and 2). The second area is 160 km south-east of Dinar, around the town of Seydeşehir and is an area of known caves. It is the subject of a separate paper (Self, this issue).

The climate of the Dinar/Çivril area is dry Mediterranean with summer drought and winter rain, giving an average annual precipitation of about 700 mm and resulting in a characteristic semi-arid landscape. Soils are generally shallow and stony, supporting either scrub vegetation or open coniferous woodland, depending upon altitude. In the poljes and river valleys deeper alluvial soils are present which, although still stony, support grasses and crops such as cereals, melons and sunflowers. Irrigation is required to support these crops in some areas, whilst in others drainage channels are necessary to keep previously marshland areas dry and flood-free. This drainage commenced in the late 1940s and had the additional benefit of reducing disease caused by marsh insects such as mosquitos.

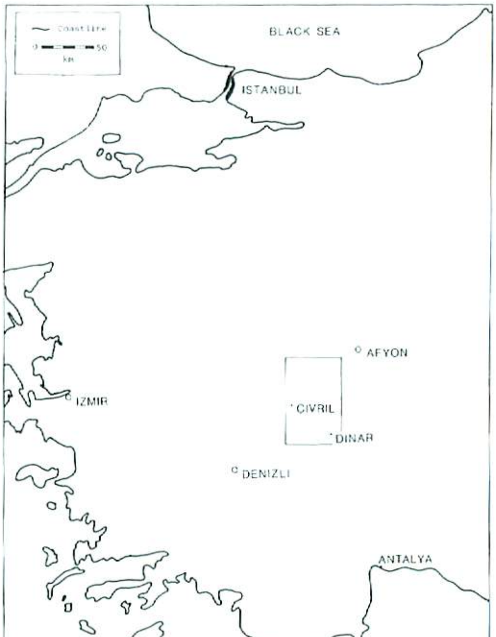

Fig. 1—Location of the Dinar/Çivril area in Turkey

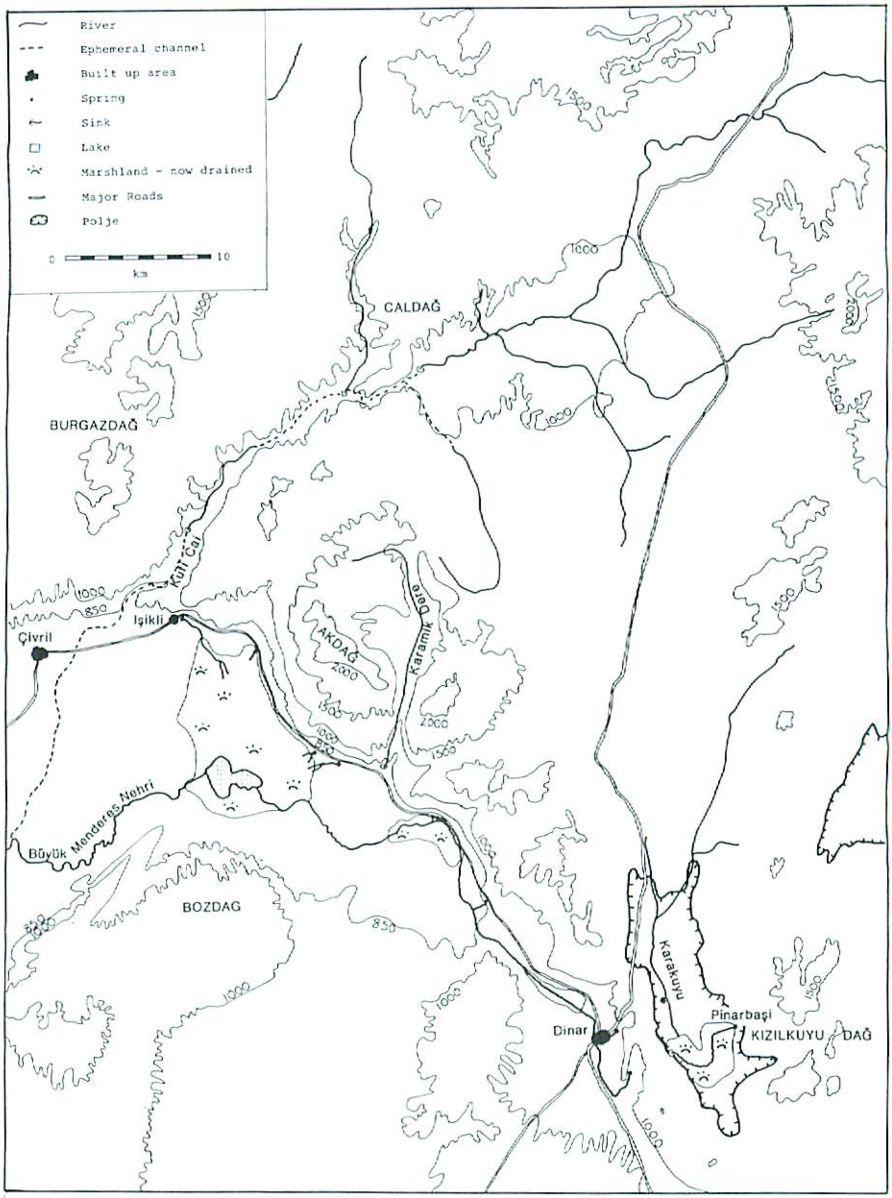

FIG. 2—DINAR/ÇIVRIL AREA, TURKEY

TOPOGRAPHY AND GEOLOGY

This report concentrates on some of the features of the area from which the headwaters of the Büyük Menderes Nehri rise. The river runs through a 12 km wide flood plain at 800–900 m above sea level and is bounded to the south by the 1,350 m high Bozdağ Massif and to the north-west by the Burgazdağ Massif which reaches 1,990 m. To the north-east, and of most interest to the expedition, lies the Akdağ Massif which rises very steeply to an elongated rolling upland plateau at 2,700 m.

The Akdağ and Burgazdağ Massifs are composed of limestones described by Campbell (1971) as the Mesozoic Carbonate Series, their age ranging from Lias to Eocene. These are fine-grained limestones, massive in places, but thinly bedded with shale bands in others. On the whole they are well fractured, but they are less so in the Karamik Dere, enabling the development of a high canyon. On Akdag these limestones dip between 45° and 60° in a south-westerly direction. Surrounding the massifs are more recent lacustrine deposits of Pliocene and Quaternary age (FIG. 3), some of which overlie the pre-Mesozoic basement rocks which form part of the Bozdağ upland area. In the east around Dinar, Miocene conglomeratic limestones form the upstanding masses.

The central Akdağ Massif is dissected by a number of steep-sided valleys and canyons. The most spectacular of these, a 150 m high canyon through which the Karamik Dere flows, contains the only surface water to be found in the massif during summer. Between the canyons and valleys there are scree slopes up to 400 m long, 30 m wide, composed of very angular cobble sized material, formed by frost shattering of well-fractured rock faces. The dissected upland surface has steep slopes with little soil and poor thorn scrub vegetation scattered with stunted coniferous trees. Large outcrops of rock up to 40 m high are present; however there is an absence of closed depressions, limestone pavements, rillenkarren, kamenitzas, or other surface solutional features. Sub-surface solution however is evident at some roadside exposures

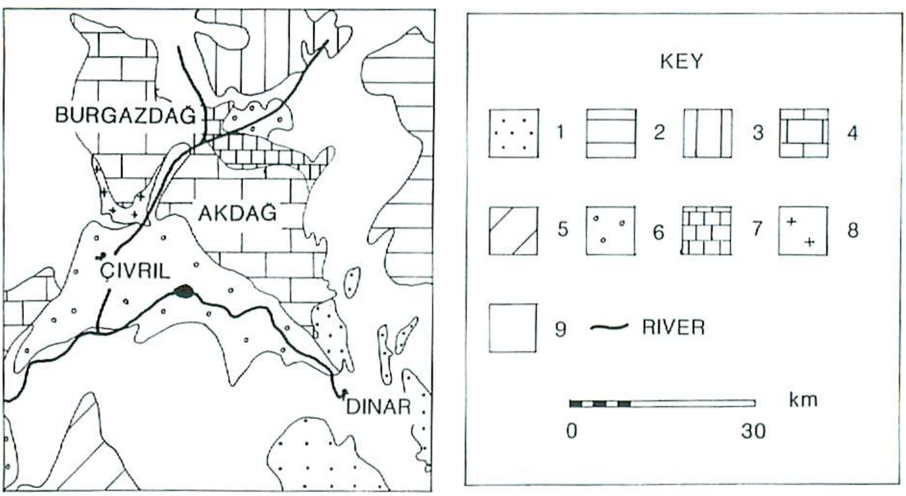

FIG. 3—GEOLOGY OF THE DINAR/ÇIVRIL AREA
Key: 1. Miocene conglomerates. 2. Recent Neogene volcanics. 3. Alamya Massif—schists and marbles. 4. Mesozoic Carbonate Series. 5. Pre-Mesozoic basement rock. 6. Alluvium. 7. Middle Triassic limestones. 8. Metamorphic rocks dominantly composed of schists. 9. Lacustrine Pliocene and Quarternary deposits.

lower in the massif where smooth rock at the soil/limestone interface can be seen. On the Akdağ ridge, some 20–30 m wide, the undulating topography is characterized by thin, grass-covered turf and low outcrops of angular rock debris, some of which include pieces of broken calcrete. The fact that the calcrete is broken, and the absence of currently forming material, suggest that it is quite old, possibly being a remnant of a once wetter, more tropical climate.

SPRINGS FED BY PERCOLATION WATER

During the search for caves, many of the springs feeding the headwaters of the Büyük Menderes Nehri were visited. They are of great interest as they are the major sources of water during summer. The first of these springs is at Pinarbasi where water issues from an impenetrable horizontal fracture some 50 m long, discharging at over 100 litres/sec (l/s). Pumps supply several of the surrounding villages with water from this percolation-fed spring whose source is in the adjacent Kizilkuyu hills. The spring issues into the Karakuyu polje (FIG. 4), flows across it, and sinks into the north-eastern side of the Dinar Akdağ massif. The massif is composed of Miocene conglomeratic limestones which are very well fractured, with no accessible openings either in the hills above or at the sink itself where the water sinks into the bed of a pond. Construction works at the pond associated with drainage channel improvements could not be entered and this prevented a dye trace being carried out. The most likely place for the water to emerge is 100 m lower on the south-west side of the Akdağ Massif, this resurgence being the only one in the locality large enough to account for the amount of water sinking. Travel times are probably quite rapid, flow taking place through a network of enlarged fissures or a conduit. The water then remains on the surface to form the upper reaches of the Büyük Menderes Nehri.

At Dinar, there is a second tributary of the Büyük Menderes Nehri. The spring issues from a fracture in the hillside at around 50 l/s into an artificial lake. Close to the spring is Sucikan Cave, the only significant cave in the

FIG. 4—THE KARAKUYU POLJE LOOKING FROM THE NORTH-WEST. THE STREAM FLOWS ACROSS THE POLJE FROM THE LEFT TO SINK INTO THE DINAR AKDAĞ ON THE RIGHT-HAND SIDE OF THE PICTURE

whole area. It is about 75 m long, with one small chamber (FIG. 5) containing a colony of bats which, judging by the guano deposits, had been in residence for some time. The rock in the cave is very well fractured and is unstable in places. Standing pools of water indicate the adjacent lake water level, but no flow could be observed within them.

Travelling north-west from Dinar to Çivril along the limestone/alluvium boundary seven more springs were encountered, six of which issue from impenetrable horizontal fractures, and one from an open underwater passage (the Işikli resurgence). The first six springs have discharges of between about 10 and 100 l/s and they drain the central and western Akdağ Massif. Only one sinking stream was found, however—the Karamik Dere. This runs on the surface for the whole of its upper reach before sinking gradually into its gravel-strewn bed about half way along its length. It reappears again about 2 km lower and flows for another 2 km before finally disappearing, again into its pebble bed, just before the limestone/alluvium boundary. The valley of the lower part of the Karamik Dere was found to be far wider than the summer flow requires; furthermore, its bed is dominantly composed of large rounded boulders, cobbles and pebbles, even though surrounding scree slopes are of very angular material. This suggests that the river experiences very high winter flows along the full length of its bed to the Büyük Menderes Nehri in the centre of the alluvial plain.

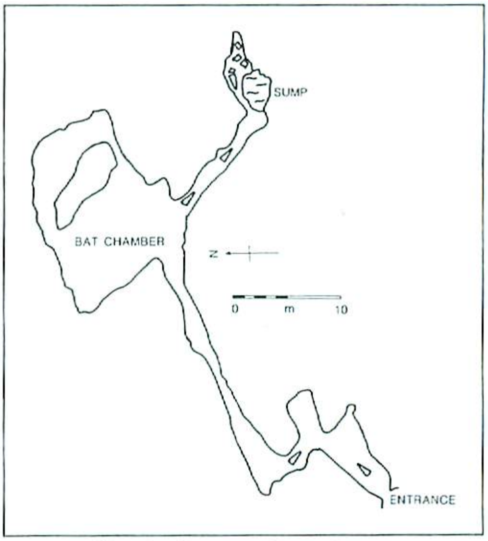

FIG. 5—SUCIKAN CAVE, DINAR

IŞIKLI RESURGENCE

The resurgence at the village of Işikli, some 40 km north-west of Dinar, was the site of both ancient Greek and Roman cities. The water here had a conductivity (which is directly related to hardness) of about 760 μS/cm, compared to the range of values in the other springs of 400–500 μS/cm. It was also slightly colder at 13°C compared to 14°–15°C. Furthermore, it emerges from an opening 1.5 m wide by 1.0 m high which continues underwater for at least 4 m, rather than from the usual impenetrable gap. Unfortunately it could not be explored as no diving equipment was available. The opening is shielded by a concrete screen built to prevent contamination of the water, which is used in Işikli and pumped to fifteen other villages. It is also used as a supply for the farming of crayfish.

The discharge of the resurgence was gauged in a section of artificial channel some distance from where it emerged, this being the only place where accurate measurements could be made. The value obtained did not include water extracted at the source, but it did include that which bubbled up into the floor of small lakes below the resurgence. The discharge was estimated to be about 2.5 m^3/s. Combining this figure with climatic statistics for the area allows an approximate value for the catchment area to be determined:

$$\text{Mean annual precipitation} = 700 \text{ mm}$$
$$\text{Annual evapotranspiration} = 350 \text{ mm}$$
$$\text{Annual discharge} = 79 \times 10^6 \text{ m}^3$$
$$\text{Discharge} = \text{catchment area} \times (\text{precipitation} - \text{evapotranspiration})$$

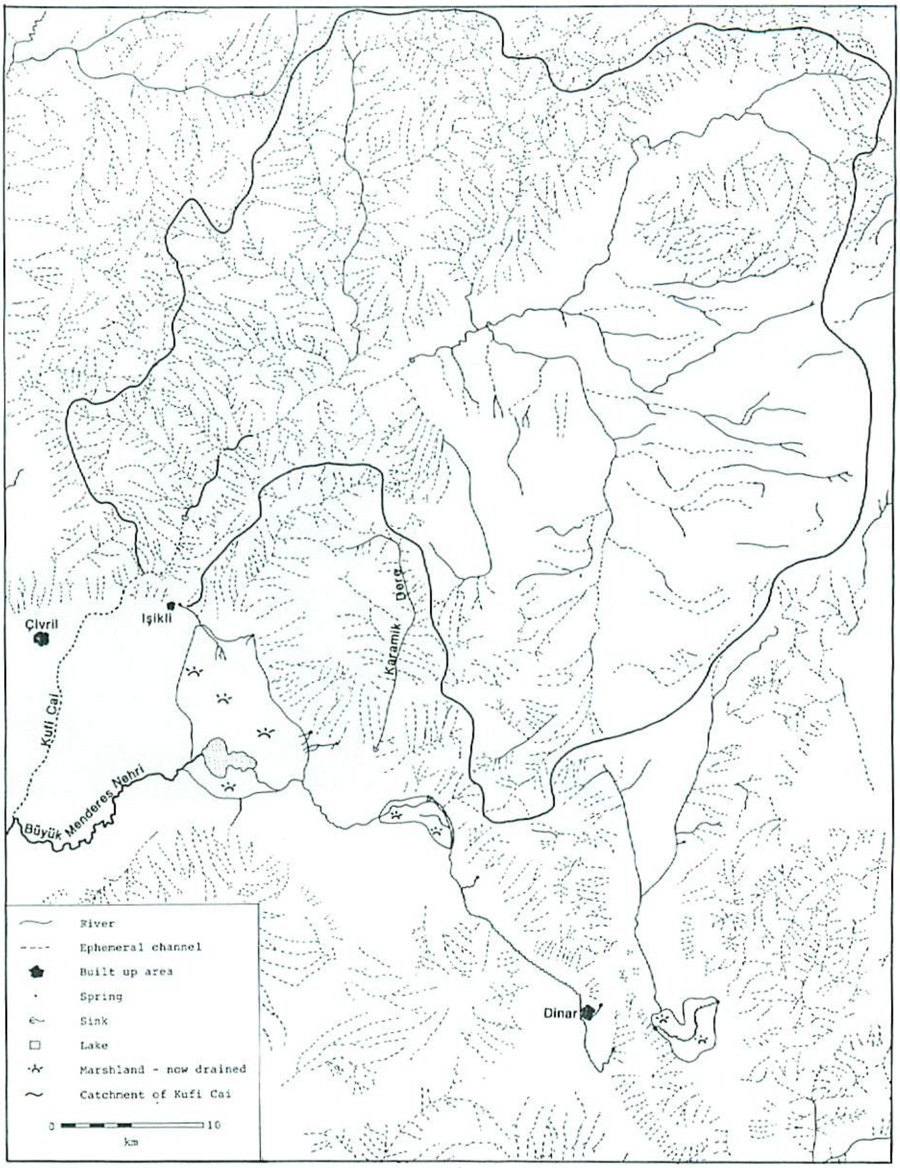

FIG. 6—CATCHMENT AREA OF THE KÜFI CAI

If no surface run off is assumed, the minimum catchment area is 276 km^2, an area considerably greater than the limestone outcrop in the vicinity of Işikli. The limestone hills to the west are separated from the resurgence by the valley of the Küfi Cai, whilst Akdağ to the east is drained by the springs described above, and the Karamik Dere. The only remaining source for the resurgence is the large river catchment of the Küfi Cai, a tributary of the Büyük Menderes Nehri lying to the north of Işikli. This catchment has a permanent river in several locations (Fig. 6), however much of the flow is ephemeral, especially the smaller tributaries. The last surface water is seen flowing in the river 20 km north of Işikli (Fig. 7) before disappearing into its bed of gravel to cobble sized material. This water source would also account for the high conductivity of the Işikli resurgence, the surface water becoming concentrated due to evaporation along the length of the river, and then mixing with lower conductivity limestone water in the aquifer. At the sink the water is some 300 m higher than the resurgence, creating a shallow gradient on the potentiometric surface and thus slow-moving sub-surface water through the fractured bedrock.

Fig. 7—Canyon in the lower end of the Küfi Cai catchment at the site where the last surface water in the river can be seen

The Küfi Cai river has a surface catchment area of 830 km, with two distinctive drainage patterns, depending upon the local geology. The first occurs over lacustrine deposits, and is characterised by a low drainage density and essentially perennial flow. The second is over carbonate rocks which exhibit a very high density network of ephemeral channels, devoid of water for much of the year. During the winter, when heavy storms occur, the ephemeral drainage network removes flood water rapidly, following surface routes to the Büyük Menderes Nehri. Some of this water will recharge the aquifer, which must have considerable storage capacity to supply the base flow at Işikli which continues through the dry summer months. Part of this storage capacity is provided by the alluvial flood plain associated with parts of the river (Fig. 3) and forms an important water supply via numerous wells. Such wells showed the water table to be only five or six metres below the surface, even though the area had had no rain for the previous four months. It thus appears that the alluvial deposits augment the water storage capacity of the fractured limestones.

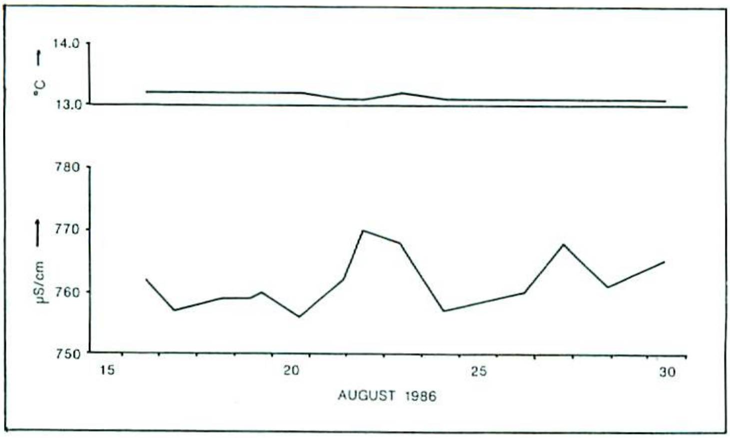

FIG. 8—TEMPERATURE (UPPER LINE) AND CONDUCTIVITY (LOWER LINE) AT IŞIKLI RESURGENCE
Instrument error for conductivity measurements is ± 10µs/cm

The area experienced its first rain for four months just after our arrival, thus providing an ideal time to monitor the response of the resurgence. For two weeks after the storm the conductivity and temperature of the resurgence were recorded daily (FIG. 8), but no significant changes in either were observed. This supports the hypothesis of a high storage, long residence time aquifer. Unfortunately a dye trace could not be undertaken to establish the travel time from the river as no discrete sink was present and the surface water was used for watering animals. In any case it was unlikely the dye would have reached the resurgence before it was time for the expedition to leave.

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