AREA REPORT

Club: *VSA*	**Name of Area:** ***Drik Drik (3DD)*.**	**Author:** ***Ken Grimes.***	**Date of trip:** *4-4-1999*
Caves visited: *Surface (including plateau, scarp and dolines of DD1 & DD3) & entered cave DD4.*			
Title of report (if any): *Geological interpretations of Drik Drik area (Gambier Karst).*			
Names in party (indicate Author, Leader) *Glenn Baddeley, Ken Grimes, and various other VSA & CCV cavers (see separate report by G.Baddeley).*			

Report:

Glenn Baddeley organised an Easter trip to the DD-4 area with about a dozen VSA and CCV cavers involved in underground exploration & mapping, and surface exploration, geology and tagging. This was part of a continuing exploration effort in the area since interest was revived a couple of years ago when George Christie reported the previously unrecorded cave in the DD-4 doline. I attended only for one day, in which I looked at surface features and entered DD-4. This report concentrates on my (rather brief) geological observations and deductions, together with a summary of previous geological observations in the immediate area. The geology is more complex than in most Victorian cave areas, hence this detailed report.

Regional Geology

3DD-4 and several other caves occur along a scarp east of the Drik Drik - Nelson Road about 10km south of Winnap. The area is part of the Gambier Karst Province which extends from South Australia into western Victoria (Grimes & others, 1999 & in press). The scarp. which runs NNE, separates a basaltic plateau of Jones Ridge to the east from lower, undulating dunefields to the west (Figure 1). Cave development is mainly in the Tertiary Gambier Limestone, but some entrances and dolines are in overlying Quaternary dune limestone and other rock types. On the plateau subjacent karst dolines have formed through the volcanic capping.

The rock units in the area are listed below, working from oldest to youngest. Their spatial relationships are indicated in the cross-section of Figure 2.

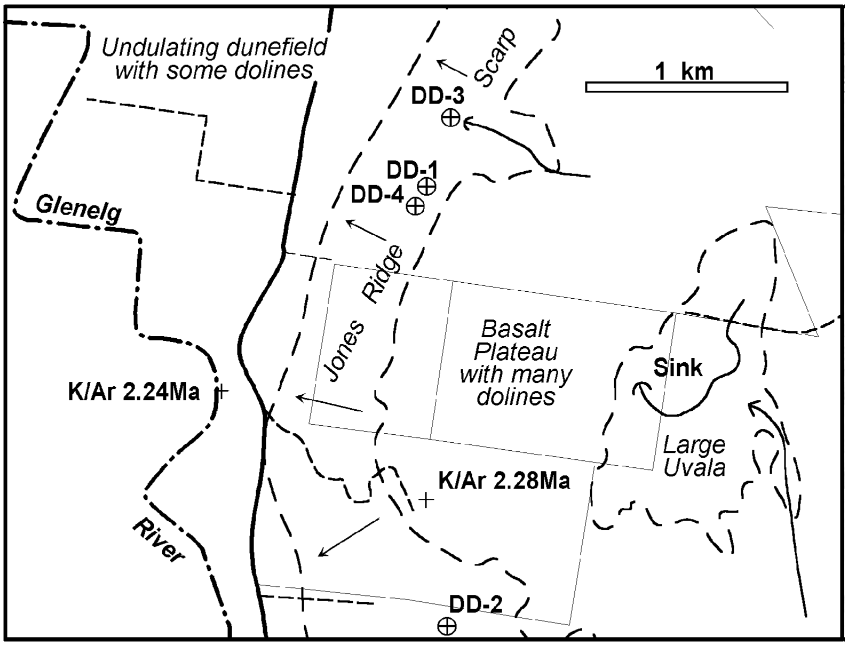


Figure 1: Location Map

Gambier (or Port Campbell) Limestone. A Tertiary (mainly Miocene) marine limestone. In this area it tends to be a pale grey to cream coloured, massive to thick-bedded (horizontal), fine to medium-grained, muddy calcarenite (sand-sized limestone). Primary porosity and permeability appears to be low to moderate - but some more-permeable beds are suggested by horizontal bands of speleothems on the walls of the cave. The rock is soft and friable and seldom seen in outcrop, but is well exposed in the cave walls. The few surface exposures were case-hardened by secondary calcite cement and difficult to interpret. A variety of Miocene to late Oligocene marine fossils occur within the limestone, and Reto Zollinger found sharks teeth in DD-4 during the trip. Some well-spaced vertical jointing was visible within the DD-4 cave. *This is the primary host rock for the caves of the area.*

Whalers Bluff Formation. The local unit has also been correlated with the Coomandook Formation of South Australia and there is some debate about the nomenclature, which need not bother us! This late Pliocene to earliest Quaternary marine unit occurs in the river cliffs to the west, and extends to north of Dartmoor and as far as Portland, so it could easily be present in the DD-4 area but has not been positively identified. If present, it would form a thin horizontal bed above the Gambier limestone and below the dune limestones. Its age relationship to the basalt is dependant on ones interpretation of an outcrop in the Glenelg River where it appears to postdate the basalt (Singleton & others, 1976; Kenley, 1971). The flat-bedded calcarenites seen in some of the dolines might be this unit, but for now I have adopted the simpler interpretation that they are younger beach deposits of the Bridgewater Formation (see below). Along the river the unit comprises flat-lying thin-bedded calcarenites with a significant quartz content in addition to the calcareous sand, and with shelly fossils - including large oyster shells. Because of the quartz impurity and its low strength *its cave potential would seem to be fairly low.*

Newer Volcanics. Basalt lavas cap the plateau and crop out in the upper part of the scarp. These are part of the Newer Volcanics province, which ranges in age from Pliocene (5 Ma) up to quite recent times. Two samples of the basalts from the plateau just south of DD-4 have been dated by K/Ar at 2.3 million years (Singleton et al, 1976); potentially overlapping in age with the Whalers Bluff Formation, and the oldest dunes of the Bridgewater Formation. Basalt is generally absent from the down-faulted block west of the scarp apart from a few outcrops reported in cliffs of the Glenelg River (Kenley, 1971, p127; Singleton & others, 1976) which have similar K/Ar ages to the plateau top. The scarp at the edge of the plateau would thus seem to postdate the lava flows.

The thickness of the basalt is hard to estimate as basalt rubble extends down the scree slope and hides the contact with the underlying limestone. The thickness probably varies through the area as the flows would have been over an irregular (possibly karstic) surface. In the scarp immediately above the DD-4 doline there is at least 7m of solid outcrop of basalt, and the highest outcrop of limestone

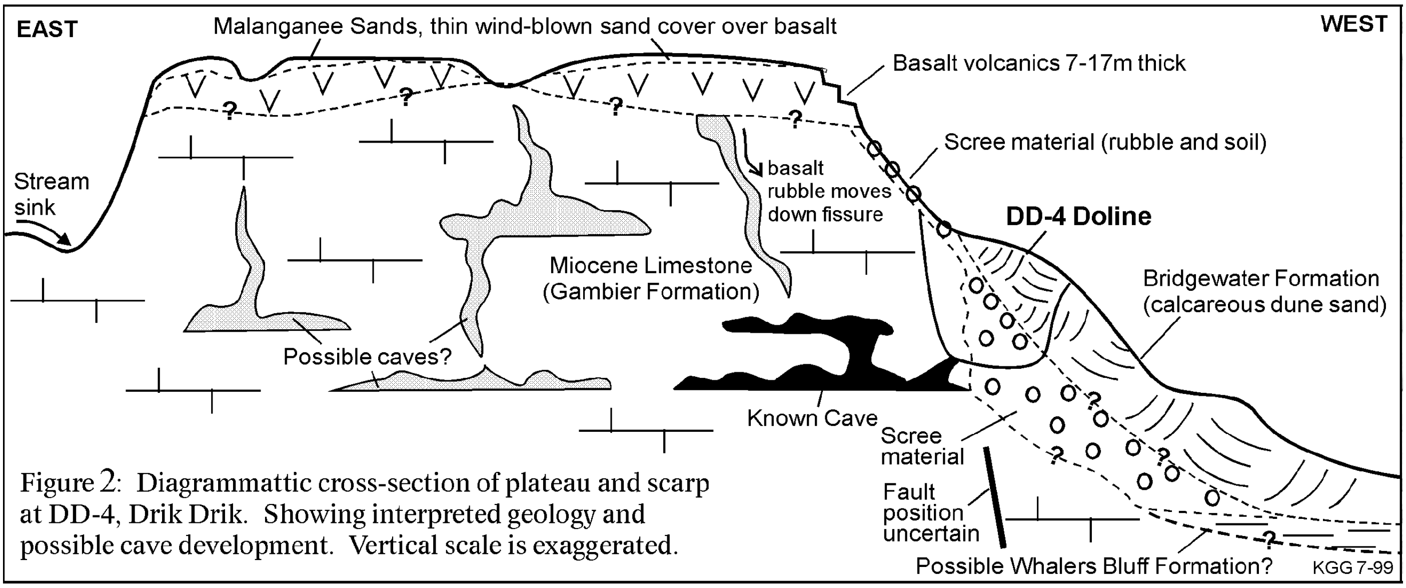


Figure 2: Diagrammattic cross-section of plateau and scarp at DD-4, Drik Drik. Showing interpreted geology and possible cave development. Vertical scale is exaggerated.

through the scree beneath this is another 10m below the base of the outcrop. Thus the maximum possible thickness there is 17m, though the true thickness is probably closer to 7m. At the eastern edge of the plateau the thickness also has to be less than 17m - again based on the highest visible limestone. On the plateau surface some of the numerous dolines have outcrops of basalt in them, but some also have areas of sandy soil towards the base that might indicate penetration through the basalt into the underlying formations. However that interpretation is fairly speculative. The best we can say is that there is at least 7m of basalt above the DD-4 doline, and that the thickness could be somewhat greater or less elsewhere in the plateau, but probably never exceeds 20m (see Figure 2).

Bridgewater Formation. This unit comprises Quaternary calcarenites, being dune and beach sands formed at a time when the sea level was higher (and the land lay lower) and there was a coast close to or possibly even lapping against the scarp. The age of the formation overlaps with that of the basalts, but is mostly younger. However, in the DD-4 doline we can see that the dune sands overlie a scree that contains basalt fragments (Fig 2), so the local dunes are definitely younger than the basalt. The limestones are pale brown calcareous sands, composed of shell fragments with a small percentage of quartz. Some exposures seen in the northern dolines are flat-lying and thin-bedded, which suggests a beach or intertidal environment, others show the characteristic large cross-beds of sand dunes. Good examples of cross-bedding can be seen in the walls of the DD-4 doline (Figure 2). *The Bridgewater Formation hosts extensive cave systems elsewhere (e.g. at Bat Ridges) but in this area it is only seen in the entrance dolines and the main cave development is in the underlying Tertiary Gambier Limestone.*

Malanganee Sands. Thin sheets or low dunes of Late Quaternary to Holocene quartz sands blanket many parts of the area. These are derived from the residual quartz-rich soils that developed on the surface of the older calcareous dunes of the Bridgewater Formation. They are of main interest where they occur on the plateau surface. The geological map shows extensive areas just to the north of the DD-4 area, but in the DD-4 area they were considered too thin to map. The thickness is generally less than a few metres to the north and locally all one sees is a thin zone of quartz sand mixed into the basalt soil. *There is no cave potential, and the material may well clog potential entrances in older limestones.*

Slope deposits. Along the scarp, basalt rubble and soil from above has rolled and slid down to form a wedge-shaped deposit that hides the original steeper face. This material can be seen in the DD-4 doline (Fig 2) where it lies beneath cross-bedded dunes of the Bridgewater Formation - indicating that there it is older than the dunes. However the process is a continuing one and younger slope deposits also occur and frustrate our attempts to locate the contact between the basalt and the limestone. These deposits may also have buried old cave entrances. In the DD-4 doline the material consists of cobbles of limestone and weathered basalt in a matrix of light-brown to brown-grey mud. The basalt cobbles have weathered back to form flat faces flush with the cliff, which suggests that this doline cliff has been present and stable for some time - in spite of its seeming instability! None-the-less I would caution against interfering with the cliff face or standing near it during rainy periods as that could still trigger small or large rock-falls.

Cave sediments. There are several types of cave sediment in DD-4. In some of the upper level passages we find *basalt gravel:* pebbles and cobbles. I was told that in one passage the quantity of this gravel is sufficient to block access. This material must be coming from the plateau, and indicates reasonable sized connections with the surface (as illustrated in Figure 2). These are possibly soil- and rubble-clogged shafts located beneath dolines such as those seen on the plateau surface. The present stream passage also has some basalt pebbles on the floor.

Mud banks are common in the main level, but also occur in the upper levels up to 5-6m above the present stream. The modern banks in the stream level are soft, moist, laminar muds with occasional beds of silt and fine sand that show small cross-beds. They are probably submerged for part of each wet season (?). The present stream has cut a channel through them. The bedding of the laminar muds is draped over irregularities in the floor and walls, suggesting that it settled out from still water. The muds are most common in the sections immediately upstream of the current rock-piles. This suggests that they probably formed at times when the through-flow was blocked by collapse in the doline area or within the cave and lakes backed up behind the blockage. The small cross-beds in the silt and sand indicated deposition from an active cave stream - presumably when the blockages were cleared out. The deposits in the upper levels are similar, but dry and compact (Photo). These fill pockets in the walls, and occur, with mud-cracks, on the floors.

Breakdown rubble partly blocks the passages in several places. Some of this is mud-coated and so predates the last flooding episode, other parts look more recent. Some of the material coating this rubble could be old guano.

The age of the basalt gravels is uncertain, but its dominance in the higher level passages, which are presumably older, suggests that most of it predates the cutting of the present stream-level passage. The scattered pebbles in the present stream could be reworked from these higher levels as much as from the surface. The mud may have formed in several stages. The upper levels are 3-8 m above the present stream, and a major backup of water would be needed to flood them at present, so the muds there are probably older than the mud banks at the present stream level which appear fairly recent. These deposits probably formed at times when the outflow was blocked by collapse in the doline, or within the cave, and so would be intermittent things, with little predictable relationship to other events.

Modern soil. On the plateau a heavy dark grey clay soil has formed from weathering of the basalt. This contains an admixture of quartz sand which would be derived from the Malanganee Sands. The cave muds may be derived from this material. Active soil creep is moving clay and basalt rubble down the scarp. Likewise on the doline sides - assisted by clearing and cattle tracking.

Landforms

The Plateau. The relatively flat plateau surface would approximate the surface of the lava flows, which are fairly thin. But it is punctuated by closed depressions. These dolines would be subjacent karst features; that is, they formed by subsidence or collapse of the insoluble surface rock into cavities dissolved in the limestone below. Some of these dolines are fairly steep-sided, suggesting relatively recent subsidence. Others are shallow and may be older degraded features. The quartz sand would have been blown over the surface by the wind. Soil heaving would have mixed it into the clays weathering out of the basalt.

The east scarp The eastern scarp was quite steep where we visited it, above a stream sink (Fig 1). Here, a large uvala-like hollow contains a stream sink at the base of the scarp, about 25m below the plateau top.

The west scarp (Jones Ridge). The linear nature of this feature suggests a fault scarp, with the east block uplifted, and it is shown as such on the geological maps with the fault line about 500m west of the top of the present scarp, which has retreated east since it formed. The faulting predates the dunes of the Bridgewater Formation, which are piled up over the scree deposits. It may post-date the lava flows, as the contemporaneous basalts reported to the west are at lower levels. However, about 5km to the southeast a tongue of basalt occupies a valley that appears to have been cut back from the scarp - so perhaps the scarp was already there and the basalts flowed over the edge. Possible alternative interpretations (to faulting) are that the scarp was eroded by either an early course of the Glenelg River, or by coastal erosion prior to the formation of the beach and dune deposits of the Bridgewater Formation.

A *terrace* half way down the slope of the scarp is significant. The dolines associated with the caves (DD1, DD3, DD4) are all at the same level, and on this terrace. North of DD-3 a blind valley that cuts back into the plateau also terminates at this level. Why is this? Does the terrace indicate some sort of structural control (e.g. a narrow down-faulted block between two faults?), or does it just represent the top of an old dune ridge of the Bridgewater Formation?

Undulating dune plain. To the west of the scarp is an undulating dune plain formed partly on the calcareous dune sands of the Bridgewater Formation, and partly on younger quartz sand sheets and dunes of the Malanganee Formation (see geological maps). In this area the broader hollows are mostly dune depressions but some smaller and sharper-defined depressions are karst. Cave potential would be best to the west, near the river, and at the foot of the scarp where we should be looking for active or abandoned springs which may be fed by enterable cave passages.

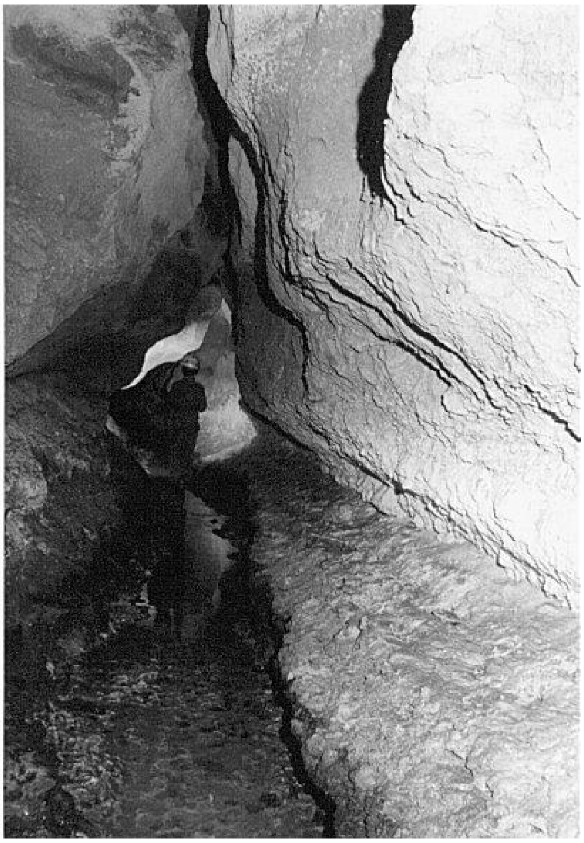
Glenelg River. At present the river mostly lies 2-5km to the west of the scarp, but to the south of DD-4 it comes within 500m of the southern end of the scarp. In the late Tertiary or early Quaternary the river could have been closer and stream erosion may be an alternative explanation for the scarp. It is possible that the stream in DD-4 turns and runs west from the doline to the river.

Karst features.

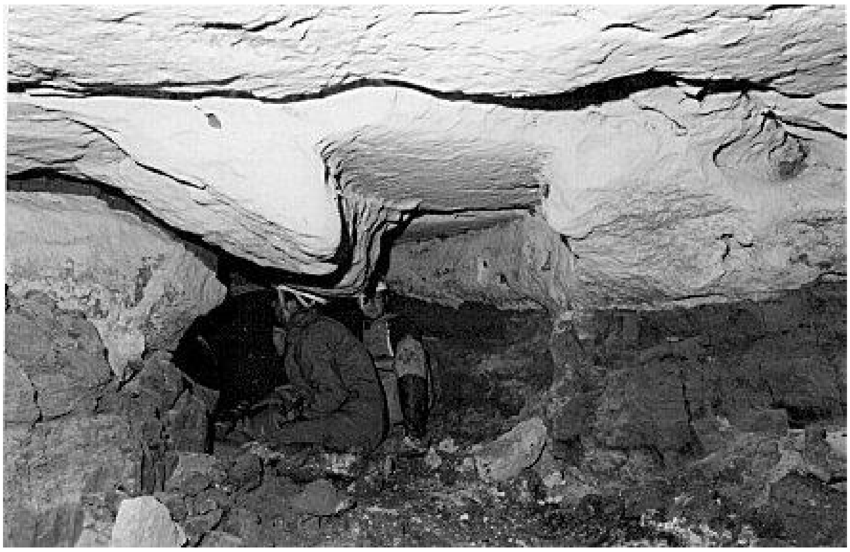
Surface Karst. There are numerous medium to large smooth-walled subsidence dolines on the plateau which I have interpreted above as being subjacent karst. East of the plateau is a valley with large uvalas and dolines and at least one stream sink. On the terrace at the level of the DD-4 doline there is a chain of big dolines and at the northern end a valley cut back into the plateau can be called "blind" in that it ends in a closed hollow where it joins the terrace. The DD-4 doline is 26m deep and has high cliffs and steep slopes as does the doline of DD-3. The others on this terrace are more degraded, but do have short segments of cliffs. Thus they all appear to be formed largely by collapse into underground cavities, possibly a master cave system that included DD-4, DD-1 and DD-3 (see below). A significant volume of material has been removed from the bottom of the DD-4 doline, including a lot of insoluble scree material. This indicates a major open cave system in the past - but not, alas, at present. No definite springs are reported at the scarp foot in the immediate area.

Caves. Three caves are known beneath the big dolines and associated terrace. There is little information about DD-1 and DD-3. The entrance to DD-1 is now blocked and no one appears to have entered DD-3 during the current phase of exploration. Early reports say that DD-3 contained a stream passage that flowed west for about 20m before becoming too small to negotiate.

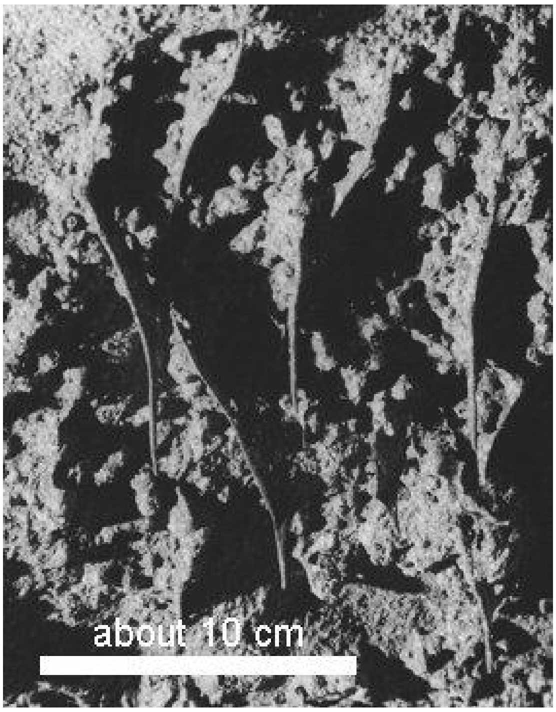
DD-4 is the largest cave in the area. I only entered the first section - up to the second rockpile, but also looked at one high-level passage. Much of what



Stream passage in DD-4.



Upper-level in DD-4. Note mud deposits to each side and paragenetic(?) stream notch in flat roof.



Mud Stalactites(?) in DD-4

follows is based on descriptions by Glenn Baddeley and Reto Zollinger. There is over 1km of linear stream passage with occasional offsets of up to 80m at right angles to the main SSE trend. This main trend is roughly parallel to the scarp, and to the fault and to the regional joint trend in the Tertiary limestone. There are no major side passages but the currently surveyed end is a T-junction. Upper level passages are visible in several places about 5-8 m above present stream (photo). These upper levels contain extensive mud banks and in one place (photo) a stream notch had been cut into the flat roof. This might indicate paragenetic erosion of the roof where the stream was forced progressively upwards by accumulations of mud in its bed. The stream canyon of the main level is up to 10 m high in places and in the entrance area this has the appearance of a vadose canyon (photo). The stream flows to the NNW. In the northern half of the cave the stream has a very flat gradient through to a set of rapids and a 3 m waterfall. Above the falls the character changes - to smaller passage with a more meandering and phreatic character. Reto reports that the roof of the stream passage is commonly quite flat - suggesting water-table control or a resistant bed.

I noticed a tendency for speleothems on the walls to form in horizontal bands with a sharp upper cut-off - suggesting that they were being fed from horizontal bedding-plains or porous beds. Reto Zollinger reports that throughout the cave the speleothems are more common on the east wall - indicating a water flow from that direction through porous beds or along bedding planes. Near the entrance there was a section of mud bank with old footprints that had been calcified and now contain pools with crystal growths. Thus the water is saturated and actively precipitating carbonate.

Also in several places there are some unusual formations which may be *mud stalactites,* They looked soft, but we did not like to touch them to check as they looked very fragile. Their form was a triangular ribbon, hanging vertically, and ending in a thin string only 1mm thick (photo). They were up to 10cm long and a muddy-brown colour. The ribbon parts frequently had small holes and gaps which gave the impression that the mud might be coating organic filaments or cobwebs. These need to be studied more closely.

DD-4 may be part of a master cave system running parallel to the scarp that also includes DD-1 and DD-3 as well as the big dolines further north. Exploration in DD-3 is therefore warranted.

Geomorphological Evolution of the area.

It is a bit early to say too much about this and some of what follows is quite speculative.

The Tertiary limestones have probably been exposed and karst features developing since the late Miocene (10 million years ago). Thus the volcanic lavas may have flowed over a karst surface when they were erupted 2.3 million years ago (late Pliocene). The lavas would have disrupted the infiltration of water from the surface into any cave systems beneath them. The edge of the plateau was probably faulted after the volcanism to form a forerunner of the present scarp. This may have occurred in the early Quaternary - and the scarp has retreated 0.5 to 1 km since. The scree slopes then started to form and being largely insoluble material of low porosity would have blocked any karst-fed springs running out from the plateau. This might have diverted the underground flow so that it ran parallel to the scarp to a (hypothetical) outflow point further north. If so the present cave system is running at right-angles to the earlier drainage - hence my interest in exploring the high-level (older) passages.

During the Quaternary, sea levels fluctuated and the region as a whole was lower. At least once in the early Quaternary the sea reached into the area and lapped against the scarp. Shallow marine and beach deposits were formed at the base of the scarp - and possibly part way up it (the flat bedded material in the dolines near DD-3). The calcareous dunes of the Bridgewater Formation are coastal features that also formed at this time.

As the basaltic lavas weathered to soil, more water would have penetrated them and solution of the underlying limestone would have formed the subjacent dolines on the plateau surface. Basalt rubble and clayey soil moved down through open fissures into the cave system. The rubble is now mainly in the upper cave levels, but the mud is everywhere. Younger quartz sand dunes were blown across the area, climbing the scarp to run, discontinuously, across the plateau. This quartz sand has become mixed with the clay soil.

Relevance to Cave Exploration.

Connections to caves from the surface of the plateau may be old and no longer easily reopened as they will be clogged with clay and basalt rubble. Digs in the surface dolines would have little potential unless there is an active runaway hole to follow. The main cave trend is along scarp rather than into plateau, but in the past the trends may have been different, and exploration of high-level passages is warranted. We need more data from DD-3. Is this also running parallel to the scarp? Has it a stream, and if so which way is it flowing? The stream sink on far side of plateau must lead somewhere, likewise water entering via the plateau dolines. So some underground drainage through and outwards from the plateau is likely - but where? Exploration for spring entrances at the scarp foot might be useful, though the scree and dune deposits may have buried any old springs that were there.

Further work should include the following.

- *Survey a profile up the scarp* in the DD-4 area and tie it to the cave map to establish the level of the cave stream relative to the scarp foot. This will indicate the level at which we could expect springs and possible old entrances along the base of the scarp. Do the higher levels within the cave correspond to surface features such as terraces or breaks-in-slope? Or to embayments that might be abandoned springs?

- *Within DD-4 do not neglect to follow up all the high-level passages*, there is potential here to cross-link to other parallel systems, or to tributaries feeding in from the plateau. Mapping of these older high level passages could give us important clues to the development of the system.

- If it is possible to get in past the rubbish, then *explore, document and map the DD-3 cave*. Is this running along the same trend as DD-4? Where does the water in the stream passage come from and what is the flow rate (if from south, it might be a continuation of the DD-4 stream)?

- Consider sampling one of the presumed *mud stalactites* for analysis (pick one that is expendable - poorly shaped, already damaged). Are they as soft and fragile as they look? Is it really mud? and what (if any) organic content (try plating out on agar?). Get some better photos (preferably in stereo).

- Follow up *the blind valley* cut into the scarp east of DD-3 to look for possible evidence that the depressions on the surface overlie a cave system that captured the valley stream flow. Digs in this area would have better potential than in other plateau dolines.

- *"Nearby features"* shown on the parish geological maps should eventually be followed up.

- Think up *names* for these caves!!! Check with the land-owner, or local history for ideas?

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