GEOLOGY OF THE MT ETNA AREA

by C H C Shannon

Summary and Introduction

The section of the book, Mt Etna Caves titled "Geology of the Mt Etna area" contains valuable information and concepts that are not readily accessible since the book has been out of print for years. This paper is a modestly updated "rehash" of the 1970 version with some additional material from Morand (1993) dealing with other Devonian limestone bearing sequences in Central Queensland.

The Devonian age rocks including the limestone are confined to an inlier, so limestone bearing country stops abruptly where it goes under the cover of younger rocks. Within the inlier, the structure is anticlinal with the "nose" near Cammoo, and East limb through Mt Etna and a Northeast limb extending from Johanssens. There are complications: dykes of easily weathered andesite make for gaps in the outcrop and a set of north trending faults repeats the nose of the structure.

Once the true bedding had been deciphered, it was possible to subdivide the Mt Etna Limestone erecting local "informal" member divisions. It would seem that the base of the thin-bedded Mt Etna Trig Member is the base of Morand's Barmudoo Formation, with the limestone and below part of his Mt Holly Formation. The map was drawn as a "superficial deposits eliminated" and is not reliable where there is in fact extensive cover.

The speleogenesis for the caves is related to water collection on bare rock catchment and is independent of, and if anything, inhibited by any prior collection of water into streams on non-limestone catchment (almost essential for cave development in "ordinary Australian" cave complexes). Yet the caves in the Rockhampton bare karst occupy more of the limestone than is the case say, at Jenolan or Yarrangobilly. A probable solution is found in the earth sumps found in many of the caves (and presumably all if you could get down to them) which are considered to generate acid of "soil air" proportions, that is several percent carbon dioxide in contrast to ordinary cave rivers which are in equilibrium with ordinary atmospheric levels of carbon dioxide. The supersaturated nature of the spring water draining from the karst is supportive of this model.

The term barekarst is better than towerkarst for the Mt Etna district karsted outcrops, since they are only marginally and locally cliffed at the boundary with the unconsolidated deposits. It is the sloping bare rock surface that decides the character of the karst.

There are other karsts which share these features most notably Yessabah, NSW ; Fanning River, Q; also the Bullita complex, NT and the North Queensland karsts.

Here follows the original article as in *Mt Etna Caves:*

Introduction

The geological interest of Mt Etna centres on the karst phenomena, which includes the highest towerkarst hills and the most accessible examples of towerkarst landforms on the Australian continent. Also, the fossil fauna of the limestone is of longstanding interest to palaeontologists. Fossils collected from the foot of Mt Etna are of early Devonian age. This fauna is old for central or southern Queensland and serves to place an upper limit on the age of the underlying basement rocks.

The Devonian strata form an inlier surrounded by Permian volcanics (Berserker Beds) and Cainozoic sediments. The Devonian rocks apparently extend as far as Milman.

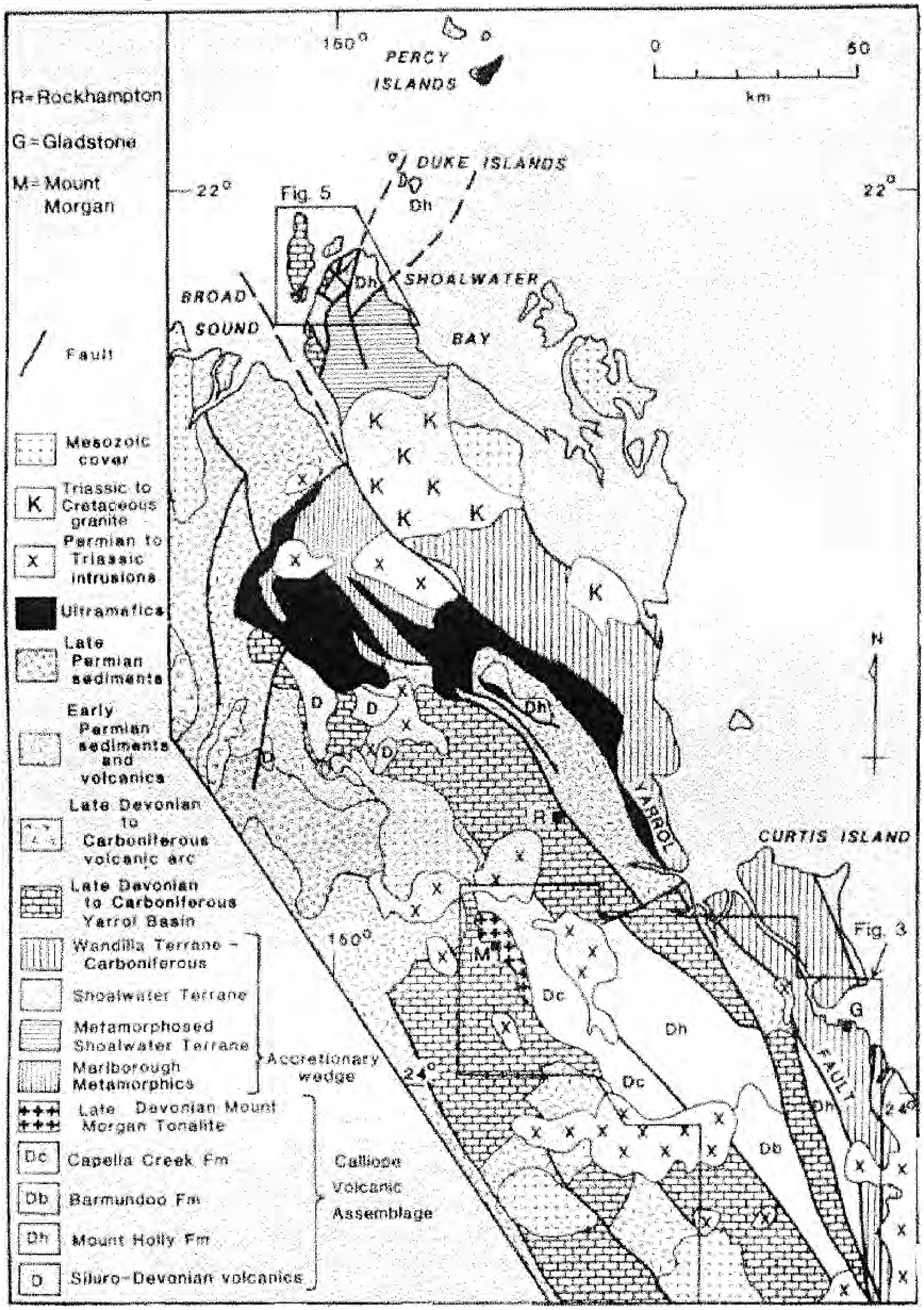
The structural problem of the Devonian rocks presented an impasse to refined work on the palaeoecology of the district. The recent solution to this problem makes possible tenable outlines for the stratigraphy and hydrology. Surface geomorphology has not yet been subject to intensive study.

Early work on the karst phenomena was not very profound, despite the popularity of the caves around the turn of the century. The first rigorous work pertaining to the caves was performed during the Second World War, when a map of six caves on Mt Etna was produced by 'Z Force' commandos under Captain S.W. Carey (later Professor). Further maps have been produced by UQSS members, but the majority of caves lack high-grade surveys at present. Speleogenesis of these caves is not directly comparable with the better known caves of temperate regions. Working hypotheses are set out, which serve to explain some of the differences.

Stratigraphy and petrology

The compilers of the most recently published map of the Mt Etna area recognise two major stratigraphic units in The Caves district. These are the Devonian Mt Etna Beds and the Permian Berserker Beds (see Rockhampton 1:250 000 geological map, provisional edition). A third unit is present which is older than the Mt Etna Beds.

The map following is from: Morand,V.J. (1993)



The sequence has its best exposure along the meridian of the Mt Etna trig. Station. The stratigraphic units are quite distinct, but dip information is scarce and so the thicknesses given below are approximations.

The sequence is as follows:

Pre-Devonian or Lower Devonian

Tufa Creek Beds', 100 foot minimum, base not exposed. Dark grey shales and massive greywacke; minor chert. The rocks in outcrop are indurated but lack slaty cleavage; though since the outcrops are close to igneous contacts both induration and lack of cleavage could be due to contact metamorphism. The rocks appear to be deep water turbidites belong to the pre-Devonian basement, but the bedding attitudes are close enough to those of the limestone to allow conformable sequence between the formations.

Igneous, age uncertain

'Pershouse Well Serpentinite', 700 foot maximum. Porphyritic green serpentinite, granular grey serpentinite, sheared grey and green serpentinite, calcite-magnesite-serpentine rock. (This last has a network of calcite veins making up to 80% of the rock with relict serpentine cores.) Gabbro dykes intrude the serpentinite. The contact of the serpentinite with the Tufa Creek Beds is presumably intrusive, but its contact with the Mt Etna Beds could either be intrusive or erosional on present evidence.

Lower to Middle? Devonian

Mt Etna Beds

3.1 'Bates Farmhouse Limestone', 100 metres. Organic limestone. The principal components are crinoid debris and stromatoporids; there are some chert nodules. A rich fauna of rugose and tabulate corals has been collected from this member, mostly from floaters.

3.2 'Speleo Camp Member', 17 metres. Reworked andesite tuff containing crinoid fossils, very coarse grained calcareous sandstone and limestone. Tabulate corals are common.

3.3 'Mt Etna Caves Limestone', 270 metres. Massive and organic limestone, some reef limestone with pink siltstone internal sediment, rare bedded limestone; sometimes with chert nodules. Most of the limestone lacks fossils, but crinoid ossicles occur in the lower part and tabulate corals and stromatoporoids occur in several beds.

3.4 'Mt Etna Trig Member', 170 metres. Laminated thin bedded siltstone, calcareous mudstone and dolomite. These sediments may represent a backreef facies transgressive over the limestone.

3.5 'Cammoo Member', 350 metres minimum. A poorly exposed unit thought to consist of andesite tuff and andesite.

Permian

4. Berserker Beds, mainly green rhyolite tuff and ignimbrite. They unconformably overlie the older rocks.

Structural geology

The structure of the Devonian rocks is difficult to determine because of the massive character of the limestone and poor outcrop conditions. The attitude of strata can, however, be determined from bedding in the limestone as defined by several criteria, which are mutually consistent. Places where bedding can be determined in the limestone are rare, but sufficient observations can be made to solve the structure. The rare thin bedded facies of the limestone has been most useful; in both surface and underground exposures, the bedding planes in this facies outcrop as etched pits and grooves in a system of parallel but unevenly spaced partings, usually about 5 cm but varying from 2-50 cm. The bedding planes are warped with low amplitude folds; wavelengths 5-100cm, amplitude a half cm to 10 cm, giving a "wavy" appearance. This peculiar appearance of bedding surfaces helps to distinguish them from the joint surfaces, which are strictly planar. It was also found that in this facies, the discoidal stromatoporoid and tabulate coral colonies were in growth position, lying flat on the bedding plane. Further dip measurements taken on stromatoporoid colonies, and also dips taken on internal sediment filling reef cavities have proven to be compatible with measurements from the thin-bedded limestone facies.

The new dip information clashed with the earlier "inclined bed" interpretation of the structure, particularly in the Johannsen's Caves area. The author developed an hypothesis of anticlinal structure to account for the 'aberrant' sequence of dips, and this hypothesis was confirmed when a continuation of the limestone beds about a kilometre long were traced through the adjacent area of poor outcrop. Details of the structure have been worked out by air photo interpretation and field work

The basic structure of the Mt Etna Beds is an anticline, with its axis trending WNW and plunging to SSE. It is complicated by a set of cross faults trending N 10 degrees E. The NW limb is apparently attenuated along an axial thrust fault, although this observed thinning of the unit may be a depositional feature of the limestone. The valley between the limestone hills is occupied partly by igneous rock interpreted here as a large faulted dyke, with a number of smaller dykes not shown on the map. These intrusions cut across the limestone strata. Crystal or Limestone peak at the South end of Limestone Ridge is an upfaulted section of the anticlinal nose, while the Johannsen's section of Limestone Ridge contains part of the nose and the start of the NW limb. Mt Etna contains the exposed section of the southern limb of the limestone outcrop.

On Limestone Peak, in particular, there is much small scale folding which is considered to be due to crumpling of the limestone in the axis of the fold.

Geomorphology

The Mt Etna area appears to be an unique class of towerkarst with affinities to arid tropical towerkarsts such as at Chillagoe, Queensland or the West Kimberleys in Western Australia. The main feature in common with the described examples of arid tropical towerkarst is the pediment surrounding the residual limestone hills, but the hills of Mt Etna are conical with much talus around the base and have practically no cliffs. Normal dry towerkarst hills are cliffed in such a way that they become cylindrical or pointed spires, and are practically free of talus at the base. Mt Etna also lacks functioning resurgence caves at the foot of the residual hills which are present in the other areas mention.

The small scale surface solution features termed microkarst are splendidly developed on the limestone outcrop. The spectacular karrenfields cover large areas of bare rock pavement. Large scale solution grooves and aretes (rinnenkarren) are the dominant form, with secondary rillenkarren also common.

Grikes are not always obvious and are frequently rubble choked. Cave entrances are generally associated with either grikes or solution pipes. The vertical solution pipes can be large enough to be called dolines, though in origin and form they differ from the type form of humid karst areas. Several other forms are present, which appear to be unique to this area.

The residual hills generally have full outcrop of rock, or thin soil cover. The pediments have thick soil cover and there is little rock outcrop even in gully sections. Adjacent to the residual hills, there is generally hillwash cover.

Gours occur in the creek below a spring about 800 metres to the North of Mt Etna. This spring is considered to be the resurgence of the system, since deposition of travertine is to be expected only if the water was coming from the limestone.

Some of the oddities of Mt Etna can be explained in terms of base level changes. Fragments of the coastal erosion surface (about 70 metres) occur at the Mt Etna campsites and the caves probably developed as a normal towerkarst with resurgences at this level. The present base level is lower, and the karst spring has taken over the outflow function of Main Cave and Johannsens Caves.

Hydrology

The climate of the Mt Etna area has a large rainfall deficit (annual potential evapo-transpiration exceeding annual rainfall) and also a long dry season. In such climates, small permanent watercourses or strongly flowing springs are oddities likely to represent the effect of special geological conditions acting to retard direct run-off and evapo-transpiration. In the area of the reserves R444 and R272, about half the surface is hard catchment, either bare rock or very thin soil cover, and the run-off from these area is diverted deeply underground, where it is protected from evapo-transpiration and so gives local conditions favourable for permanent springs.

Rain falling on the limestone outcrop runs off the karrenfield areas like water from the roof of a house. The water drains from the surface into grikes, solution pipes or talus slopes and thence into the caves, either through their entrances or avens. The caves operate as conduits bringing water into the interior of the mountain. The cave watercourses can be followed down to an earth sump or an impenetrable hole. In normal weather, the earth sumps are flat areas of earth floors, with earth rich in organic matter and loosely packed. In storm conditions, some of the sumps become temporary lakes, but drainage through sump floors is quite rapid.

Beyond the sumps, the nature of the drainage is uncertain. Some shafts in Resurrection Cave reveal short sections of active streamway fed by water from Winding Stairway, and large water flows seen inside Johannsens Cave in floods would appear to come from the caves in the northern part of Limestone Ridge.

The water in most caves is collected in horizontal cave systems near the water table and it is considered that a similar "master cave" occurs here. The horizontal network of systems of Main Cave on Mt Etna and Johannsens may once have functioned as collection and discharge routes, and caves of similar form, but closer to the present water table may be expected to be active at present.

The manner of discharge of cave water has not been determined in full. Springs with karst characteristics have been found at Cammoo Park and to the North of Mt Etna. The karst spring North of Mt Etna appears to be the principal resurgence for the area.

This spring, according to local report, was permanent until the 1960s, when a dry spell set in. The spring is located on the NE limb of the anticline and the limestone is continuous between it and Johannsens caves.

The drainage of Mt Etna presents a difficulty, since the outcrop appears to be surrounded by impermeable barriers, but a link is possible through a concealed outcrop of limestone across the valley floor. No spring discharge has been observed around the rim of the limestone outcrop, at least in recent years (meaning late 1960s-early 1970s).

The rainfall on the hard catchment areas yields an average 360 acre feet per year which would yield in principle a flow of 0.5 cusecs. Naturally, there would be large evapo-transpiration losses to be subtracted from this figure, and some addition from water falling outside the limestone area.

The discharge of water from the caves can take various forms, none mutually exclusive. In dry conditions, the spring is inactive, the water being removed by percolation and transpiration. In "normal" years, there is a surplus which flows out at the spring. In extremely wet conditions, there is a direct discharge from the lower cave entrances (eg at Olsens caves in 1956, R. Semple pers.com.).

Speleogenesis and Cave Development

The caves of Mt Etna and Limestone Ridge are classifiable into two basic types; the rainwater inflow caves which are essentially vertical caves genetically related to their present function as the runoff collectors of the karrenfield areas; and the ramifying caves which possess general horizontal passage development, often with genetically related passage networks and also tributary avens which are essentially rainwater inflow caves connecting into the system. The ramifying caves are of composite development, being former water dispersion and discharge caves now modified towards rainwater inflow type. In addition to these two categories, a third type of cave is inferred which acts as a discharge route connecting to the resurgences. It may be entirely water-filled.

The rainwater inflow caves are the most common and characteristic cave type. The simplest forms are solution pipes which are transitional to surface solution pits. More commonly, these caves are joint-controlled and expand towards the base. The more important caves descend in steps to a terminal earth sump, collecting water from tributary avens as well as entrances. The stream bed occupies most of the cave floor, and the steps are made up of rubble slopes alternating with waterfalls. These caves generally follow vertical or near vertical joints; cross-sections are basically triangular and very tall. Where the controlling joint is inclined, the hanging wall is always eroded back more than the footwall. Occasionally, there are stretches of level earth-floored cave, even at high levels within the mountain, such as in Winding Stairway Cave.

The horizontal passages of the ramifying caves are generally floored with earth or guano but sometimes with bare rock. The passage cross-sections are of doorway proportions (height :width ration of 2.5 :1) with all the corners rounded off. Some of the smaller passages and squeezes depart from strict joint control and become gently winding in plan. Stream channels take up only part of the floor, but can become channels. Caverns tend to be larger than those in the rainwater inflow caves. Rockpiles occur where the caverns run up against the outside of the outcrop. The speleogenetic processes that operate at Mt Etna require discussion in some detail since they are all somewhat abnormal by comparison with the "standard" speleogenetic processes of temperate regions and have not been described before.

1. **Organic Decay Assisted Corrosion**

This process accounts for the aggressive character of water trickling through and over organic fill, even when the water has previously deposited travertine over limestone walls. It is considered that the decaying organic content of the cave material (typically rotted tree roots) is capable of generating fresh acid inside the cave itself. The fill acts as an acid-soaked sponge pressed against the limestone and direct corrosion by the re-acidulated water occurs in some sumps where lakes form during rain. More rarely, a flowing film of re-acidulated water cuts grooves in the cave wall. The acid-sponge process occurs in miniature in wall cups, which are hemispherical cups breached by a slot in the passage itself. They are found filled with organic debris (bark and bits of tree roots, or guano).

Water trickles through the accumulated matter during rain. Some of the cups have cut downwards as much as a metre. The principal site of attack, however, is the earth sump. The sumps have periods of infill and fill removal. Fill removal is general at present. Only in these parts of the caves are there much fresh limestone exposed. Rubble blocks, apparently, are dissolved here. The rubble slopes are also sites of solutional attack. The floor beneath the rubble is generally smoothly curved. Running water is able to shift earth particles, but does not actually abrade. The rubble shifts by mass wasting rather than by fluvial action. Modern cave earths are brown, friable and highly organic. In some caves older fill is exposed (eg Helms Deep). This fill is pink and highly calcareous and includes scattered bones and snail shells. In Carn Dum at least, this material apparently filled the cave at one time.

2. **Subaerial Chalky Weathering**

This form of attack breaks down the crystalline limestone to a soft, opaque "chalk". In it's fullest development, crusts form and flake off, the rock underneath becoming deeply etched and rotted. These crusts are most common in the higher parts of caverns. The process may be driven by humidity changes, possibly with actual solution and re-deposition of the calcium carbonate. Old flowstones are attacked more severely than limestone.

3. **Travertine deposition**

The main stream channels deposit travertine over any steep drop on their route to the earth sumps. Cave coral and flowstones are particularly common; other forms are generally superficial. Practically all the flowstones are fine grained without "sparkle" and with randomly oriented crystals. Resurrection Cave provides exceptions, with the "normal" coarsely crystalline-oriented crystal flowstones (ie c-axis perpendicular to growth lines). Some of the old corroded flowstones are coarsely crystalline with oriented crystals.

4. **Erosion**

The water flowing through the caves removes all the lime in solution, but also transports limestone dust and flakes and soil particles. Larger stones are shifted if at all by mass wasting processes.

5. **Direct solution by rainwater**

This occurs to a small degree near entrances.

6. **Corrosion assisted by bat excrement**

Assumed to occur in Bat Cleft where etching and rotting of rock is carried on to a greater than normal degree.

7. **Corrasion**

Some pebbles of siltstone acquire polish in splash cups. In the water chutes where corrasion would be most expected, chalky weathering and flaking of the limestone is a faster process. The flowing water hardens the chalky crust making it relatively resistant to corrasion.

The speleogenetic processes described above operate to a much smaller degree in temperate eastern Australia, but caves which bear some resemblance to those of Mt Etna, do occur. The small potholes on Viator Hill, Texas, Q (now flooded by Pike Creek Dam) and similar caves at Timor, NSW are examples. These caves are very small, basically vertical shafts, which are never developed on sufficient scale to divert much water underground.

At Timor, they generally have fig tree roots, and at Texas, fig trees probably grew there in the past. Normally these shafts are confined to level ground, typically ridge tops. At Buchan, Victoria, some dolines have enterable caves of a form somewhat like the Mt Etna caves. The common feature of all of these caves is the lack of concentrated creeks draining into them. They are all rainwater caves, not river caves.

Nevertheless, Mt Etna remains a puzzle in that it has the most cavernous limestone outcrop in Australia, yet the caves have developed in a dry subhumid climate which would be expected to inhibit cave development. Temperate rainwater caves occur as minor features in areas dominated by river caves. At Mt Etna, there are no river caves at all. The key factors allowing cave development at Mt Etna are the karrenfields, which provide a local hydrology which offsets the general dryness of the climate; and the vine forest vegetation, which send tree roots into the caves where they provide the acid necessary for the solution of the limestone.

The Chillagoe Caves resemble the ramifying type of the Mt Etna district, but without the modifications due to rejuvenation and without the rainwater inflow cave type. Water inlets are generally through daylight holes in domed caverns. In the Kimberleys, there are small caves of the Chillagoe type (ie Window Cave), but the larger caves are river caves. The humid tropical karst areas of New Guinea and New Caledonia appear to be river cave areas, but perhaps the Mt Etna type of rainwater inflow cave occurs as well.

Stalactite - Spring Cave
Chillagoe

Contrasts between river caves and rainwater inflow caves

River caves eg Yarrangobilly, NSW or Camooweal, Q	Inflow caves of Mt Etna
Typical cross sections are either flat lying ovals or composite of ovals on the top of the other	Cross-sections are generally tall triangles
Cave passages develop away from primary joints tending to meandering forms	Cave passages remain straight but the overhanging side wall is selectively eroded
Wall sculpture is characterised by directional forms, particularly scalloping and incut benches (which make up the oval elements in the cross-section)	Wall sculpture is generally non-directional; shallow dish-like hollows to a metre across are the most common
Stream sediments are well sorted, generally rounded gravels derived from the diverted surface creek, sand and bedded clay. The affinities are with alluvial deposits	Stream sediments are poorly sorted, generally angular blocks and chips of limestone with earth and vegetable matter as the matrix. Affinities are with the hill-wash(colluvium)
Flowing water is the main solution agent. The water of the underground river attacks the cave walls directly and the fill is practically inert, but the ceiling of the cave is sometimes attacked by water percolating through gravel infilled cavities. Vegetable matter is not normally present in quantity	The cave water generally deposits lime except where it is soaking through organic fill; the acid-sponge effect is the main agent of solution. The cave floor is attacked. The acid is supplied by decaying vegetable matter in place.

Contrasts between cave areas in temperate eastern Australia and Mt Etna

Yarrangobilly, Timor etc NSW	Mt Etna
Rainwater caves few, small and often not present at all	Rainwater caves dominant and river caves not present
Caves develop by diversion of surface creeks, generally on upland plateau or through creek beds. Inflow caves do not develop on steep slopes. Swallet development generally related to creeks starting outside the limestone terrain.	Inflow caves develop mainly on steep hillsides without prior concentration in gullies. There is no diversion underground of surface creeks. Inflow caves can develop entirely from the limestone catchment. Outside runoff does not seem very helpful.
The limestone outcrop generally has some soil cover except on steep cliffs and buttresses. Karren fields consist of "tombstones"(with rillenkarren)poking through the soil cover, generally on gentle slopes with associated bowl-shaped solution dolines.	Most of the limestone outcrop is bare rock pavement with very sharp pinnacles and rinnenkarren. Dolines are replaced by solution pipes and shafts. Where there is much soil cover, cave entrances are not much found.
Wet climate and microclimate favours cave development. Active cave development confined roughly to humid climate areas and active swallets to super-humid climate (Snowy Mountains). The drier caves of the central west are generally inactive.	The climate of Mt Etna appears to be drier than any of the NSW cave area. Rainfall is moderate but evaporation is very high. Pediments, characteristic of arid climate, are normal. The moister southern and western faces are often soil covered and lack entrances.

Yarrangobilly, Timor etc NSW	Mt Etna
Most caves contain permanent water.	All caves lack permanent water.
Subaerial chalky weathering of cave walls confined to development of a soft patina over fresh rock.	Chalky weathering causes deep etching of the rock, with the development of a layer 1.5 cm thick of altered powdery rock and also thin crusts over soft chalky rock. Buttresses inside the caves become "rotted". Flowstones are attacked more than limestone.
Flowstones generally coarsely crystalline, with c-axis oriented perpendicular to the growth lines; surfaces of active flowstone have waxy or sparkling appearance.	Flowstones generally finely crystalline, without obvious orientation of the crystals. Active flowstones have a "flat" finish

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