The Glenelg River Karst Area

Susan White [1, 2] *& John Webb* [1]

[1] *Environmental Geoscience, Latrobe University Bundoora, Victoria 3058*
[2] *Victorian Speleological Association, Inc.*

Abstract

The Glenelg River karst area lies within the Gambier Karst Province, along the Glenelg River and its immediate environs. It has been known as a caving area for many years but its known caves are restricted. It forms part of a composite karst area on the coastal plains of the Gambier Karst Province. The influence of the incised Glenelg River on surface and underground water flows and the tectonic activity of the faults along the escarpment to the east of the river, has resulted in a significantly different karst landscape to the drowned cenote karst to the west. Within the Glenelg River karst there are known two sub-areas: the escarpment and the immediately adjacent incised Glenelg River karst area which, include several poorly defined cave documentation areas used by the VSA and CEGSA (Matthews, 1985): a small part of the lower southeast of South Australia (L) just to the west of S.A./Victoria border, known as Dry Creek, including areas of pine forest and farmland nearby, and in Victoria, the Glenelg (G), Drik Drik (DD) and poorly documented areas between the fault escarpment and the Glenelg River. Although formed in the Tertiary limestones, like Naracoorte, the karst landscape evolution is very different. This paper will look at the landscape development of the karst through the Pleistocene, compare it to what happened in Naracoorte and discuss potential for further discoveries.

Introduction

The Glenelg River karst area lies within the Gambier Karst Province (White, 2005), along the Glenelg River and its immediate environs (Figure 1). Although the Glenelg River has its headwaters in the non-limestone areas to the east, downstream from Casterton it flows through predominantly limestone terrain.

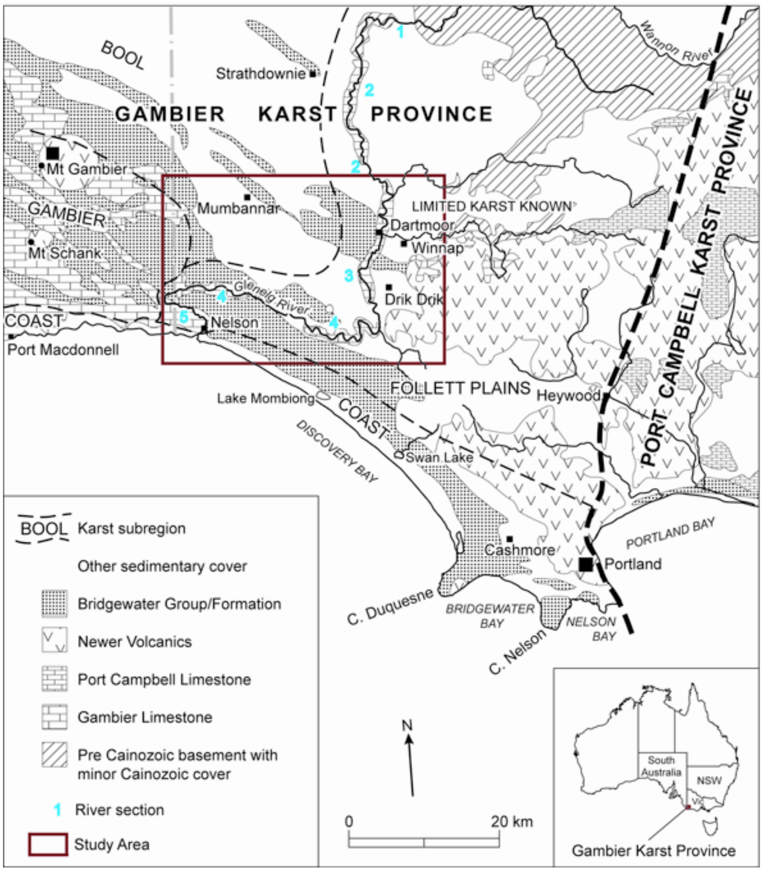

Figure 1: Glenelg River karst area: location map (White, 2005)

The karst forms part of a composite karst area on the coastal plains of the Gambier Karst Province (Grimes et al., 1995; Marker, 1975). The influence of the incised Glenelg River on surface and underground water flows and the tectonic activity of the faults along the escarpment to the east of the river has resulted in a significantly different karst landscape to the drowned cenote karst to the west and the Naracoorte karst to the north. Within the Glenelg River karst there are two sub-areas: the escarpment and the incised Glenelg River karst area.

The Glenelg River karst area includes several poorly defined cave documentation areas used by the VSA and CEGSA (Matthews, 1985): a small part of the lower southeast of South Australia (L) just to the west of S.A./Victoria border, known as Dry Creek, including areas of pine forest and farmland nearby, and in Victoria, the Glenelg (G), Drik Drik (DD) and poorly documented areas between the fault escarpment and the Glenelg River. The Follett Plain north and east of the Kanawinka Escarpment contains dune karst in Bridgewater Group aeolianites, but is not regarded as part of the Glenelg River karst area (Figure 1).

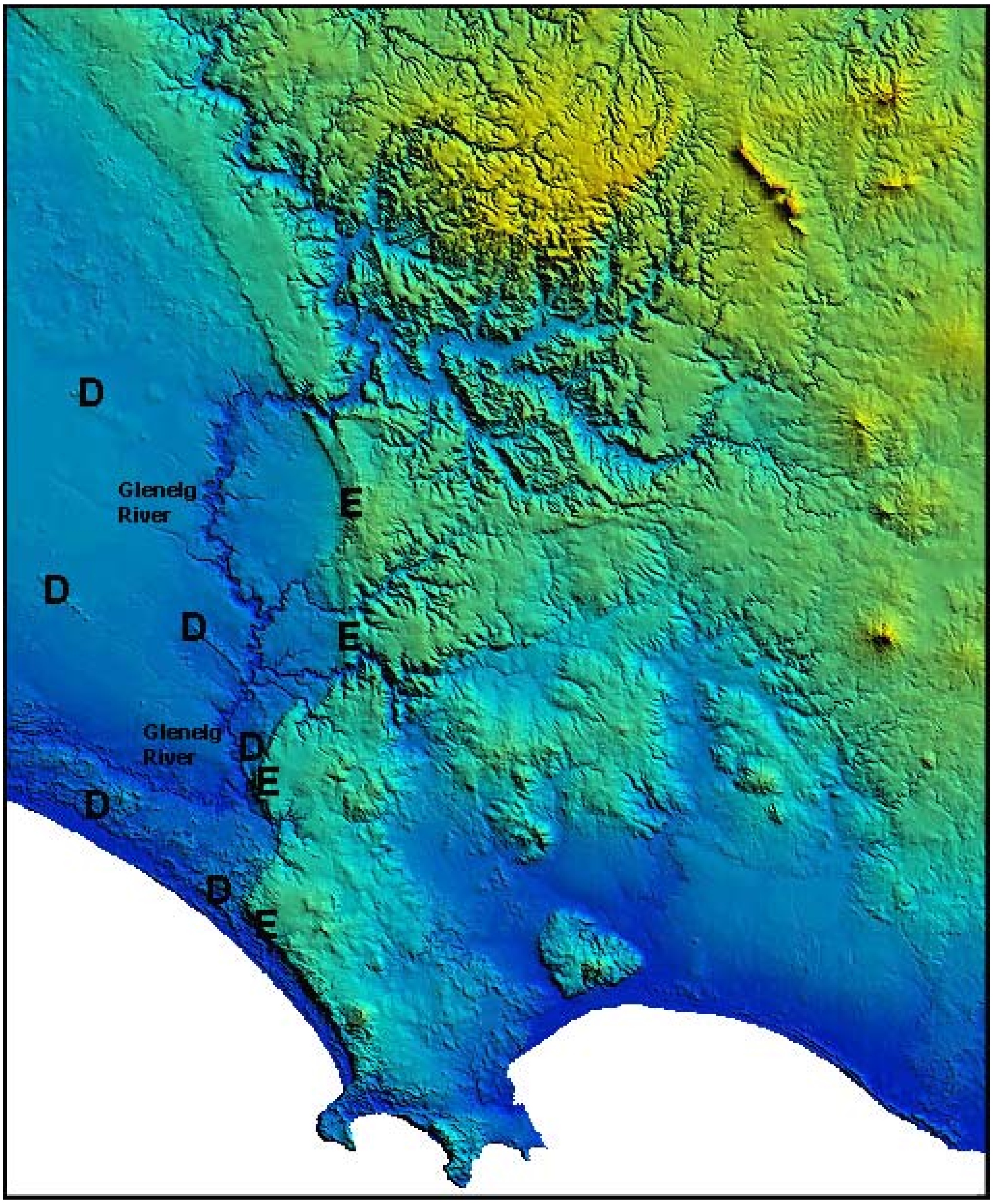

Figure 2: Digital Terrain Model showing the escarpments and dune relationships: 100 m grid cell interval digital elevation model derived from 1:25,000 topographic contours and spot heights, (after Primary Industry Research, Victoria, Bendigo). D = Dune ridge; E = Escarpment.

Geology

Within the Glenelg River area karst has developed in both Gambier Limestone and overlying Pleistocene Bridgewater Group. The main karst host rock in this area is the marine Oligo-Miocene Gambier Limestone. Pleistocene Bridgewater Group dune ridges overlie Tertiary limestones and form most of the surface outcrop. The Bridgewater Group here is low in quartz (0.6% to 5%) compared to other sites, e.g. Bats Ridge near Portland where up to 28% quartz is present (White, 1984). The stratigraphy of the Oligo-Miocene limestones in western Victoria has been the subject of some confusion and discussion (Abele et al., 1988; Gallagher et al., 1999) but the limestones outcropping along the Glenelg River are now clearly identified as Upper Gambier Limestone (Dickinson et al., 2001). East of the fault escarpment, Gambier Limestone grades laterally into non-karstic Gellibrand Marl, which is disconformably overlain by the younger Port Campbell Limestone. No outcrop of Gambier Limestone is known east of the escarpment. The Gambier Limestone and its equivalents were gently folded prior to the deposition of the Pliocene limestones and the folding is exposed in the cliffs of the Glenelg River gorge (Dickinson et al., 2001).

Pliocene basalts (between 2.2 and 2.4 Ma in age) (Aziz-Ur-Rahman and McDougall, 1972) have blanketed and infilled an erosional surface developed on the Tertiary limestone plateau to the southeast of Dartmoor and Drik Drik. The flows are ~10 m thick, depending on the underlying surface, and have been extensively weathered to thick clay rich soils.

The area has been subsequently subjected to tectonic uplift and warping and is dominated by a reactivated series of faults: the Kanawinka, Weecurra, Drik Drik, Jones Ridge, Kentbruck and Swan Lake-Bridgewater Faults, which separate the Glenelg River area from the Early Cretaceous sediments to the east. The faults form the western boundaries of elevated fault blocks tilted to the northeast, and are not topographically part of the Glenelg River karst area, except for a small area at Drik Drik, south of Dartmoor (Figure 2).

The joint directions in Gambier Limestone in the Glenelg River karst area are generally north/northwest and less commonly, at right angles to this, and these conjugate joint patterns have influenced cave development very strongly in the major cave areas close to the Glenelg River. However, in areas closer to the faults, e.g. on Jones Ridge, the jointing patterns are not as regular.

Surface Landforms and Processes

The dominant surface landforms of the area are the Glenelg River and the fault escarpments, apart from which the area has a subdued relief with dunes on the coastal plains. The interplay of soluble lithologies, a large perennial river, tectonic activity along the Kanawinka/Weecurra/Jones Ridge escarpment and the Pleistocene dunes covering the area, has resulted in a complex surface geomorphology. The escarpments represent old coastal cliffs 0.25 to 2 km east of the faults themselves.

The dunes are oblique to the escarpment and climb it in some places e.g. Jones Ridge where the large doline of DD 4 exposes climbing Bridgewater Group dunes with distinctive cross bedding, that overlie colluvium containing basalt fragments (Figure 3).

Except for the Glenelg River and its a few small tributary streams, the plains have a minimal and poorly developed surface drainage that generally is only significant during periods of high rainfall and runoff. Curran's Creek is a well defined but short perennial surface stream incised into a small gorge on the north bank of the river and is strongly influenced by the dominant northwest striking joint pattern as are most of the tributaries in this area. Most tributaries are very short and unnamed, and are perched above current river levels descending via steep knickpoints to the present river level. The larger creeks may have been previous main channels of the Glenelg River, e.g. Moleside Creek.

Much of the drainage of the area is underground. Some surface drainage has been disrupted by underground capture to form dry valleys, which carry water only during irregular periods of high flow, e.g. Dry Creek. Features such as Runaway Hole (G 43) have predominantly dry channels, which collect and funnel water underground in times of high surface flow and act as a point source recharge for the groundwater.

The Glenelg River is the largest perennial river in the western Otway Basin. Its headwaters are outside the karst area in the wetter higher altitude areas of the southern Grampians, and the river maintains a permanent flow to the sea. The Glenelg has a deep narrow valley and has cut an impressive 30 m deep gorge into the Gambier Limestone with steep cliffs incised in the southern section. The gorge is not continuous and the cliffs vary from near vertical to more gently sloping bluffs. In the gorge walls, the sub-horizontal limestone has been differentially eroded along bedding planes. The river has a complex drainage pattern, which has been modified since the Late Tertiary (Boutakoff, 1963) and is further complicated by the influence of karst ground water flow. River flow levels are maintained by the combination of relatively high rainfall in the catchment, and discharge into the river from underground streams and lateral groundwater flow.

The westerly flowing stretch of the Glenelg River downstream from Keegan's Bend is parallel to the dunes of the Bulley Range, indicating that these dunes were present when this section of the gorge was incised. The deposition of these dunes and the diversion of the river are therefore probably linked and probably occurred when sea level was below ~30 m to 40 m above present sea level.

The relatively soft limestone outcrops in the Gambier Karst Province do not develop extensive surface solutional microfeatures. Very little karren is present and in most areas, sub-soil karren is poorly developed. However, larger surface karst features, which include a wide range of solutional pans, hollows and dolines, are similar to those found further north and may be polygenetic although enigmatic (Grimes, 1996; Grimes et al., 1999). Solutional dolines, many undocumented, are widespread, e.g. G 48D and G 53D, and are also concentrated along the escarpment. They are generally conical in shape but vary greatly in depth from 1 m to 5 m. The numerous small pans and hollows scattered across the Glenelg River karst. Large elongated basin-shaped dolines, up to 500 m across and up to 10 m deep, occur in the dune ranges south of the Glenelg River and west of Moleside Creek. These dolines are predominantly solution-modified dune swales and usually have soil floors. A few contain "runaway holes", which funnel surface water underground during periods of high runoff.

At Drik Drik a group of seven dolines occurs as a spectacular set of nested solutional dolines. Some of these are nested into larger dolines in Bridgewater Group limestone on a bench half way down the escarpment. The dolines are generally blind and exhibit inverted-cone morphology.

Collapse dolines are concentrated close to the escarpment. DD 4 has a large collapse doline 26 m deep and ~20 m in diameter with near vertical cliffs (Figure 3) (Foster and McEachern, 1929). This doline contains the entrance of DD 4 and is formed in Bridgewater Group climbing dunes and has collapsed into the underlying Gambier Limestone. The collapse dolines do not extend below water table to form cenotes.

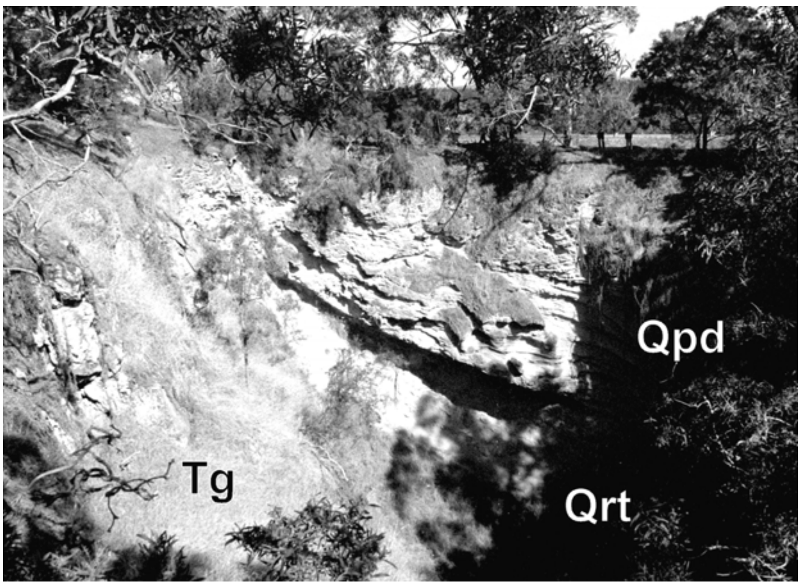

Figure 3: Climbing dunes overlying colluvium on the escarpment, DD 4; Gambier Limestone (Tg) under Talus deposit (Qrt) under Bridgewater Group dune limestone (Qpd) (Photo: K. Grimes)

Underground Features

Although over 100 features, including 67 caves, are known from the Glenelg River karst area, this reflects an incomplete knowledge of the area. Caves are concentrated in two areas, along the Glenelg River and along the escarpment at Drik Drik, and there is a paucity of known caves elsewhere. Whether the distribution and numbers of caves is an artefact of exploration or not is unclear, but current exploration indicates that more caves exist.

Most caves, including all of the larger ones, have the majority of passages developed within the Gambier Limestone. Entrances, especially solution pipes and passages connected to the surface, often pass through the overlying Bridgewater Group.

The caves occupy six general positions in the landscape:

Caves with entrances close to river level, i.e. within 1 m of the level of the present river or a tributary such as Curran's Creek, e.g. Curran's Creek Cave (G 4) (Figure 5). These often contain perennial streams.

High level caves close to the river; at 10 to 15 m above present river level with entrances in the cliffs, Amphitheatre Cave (G 2) (Figure 4).

High level caves which are not close to the river, e.g. McEachern's Death Trap (G 49) (Figure 6). These are positioned at the same level as the other high level caves, but are over 1 km from the river and are more modified by collapse and sediment infill.

DD 4, a complex two-level branchwork cave that contains an underground tributary of the Glenelg River flowing towards the Glenelg River from the higher elevation area of the Jones Ridge escarpment. This cave is atypical for the area.

Small syngenetic caves developed in Bridgewater Group aeolianites, e.g. DD 7. These often have solution pipe entrances, e.g. G 10 (Figure 9) or "Runaway" holes and dolines on the flatter plains away from the river, e.g. G 48D.

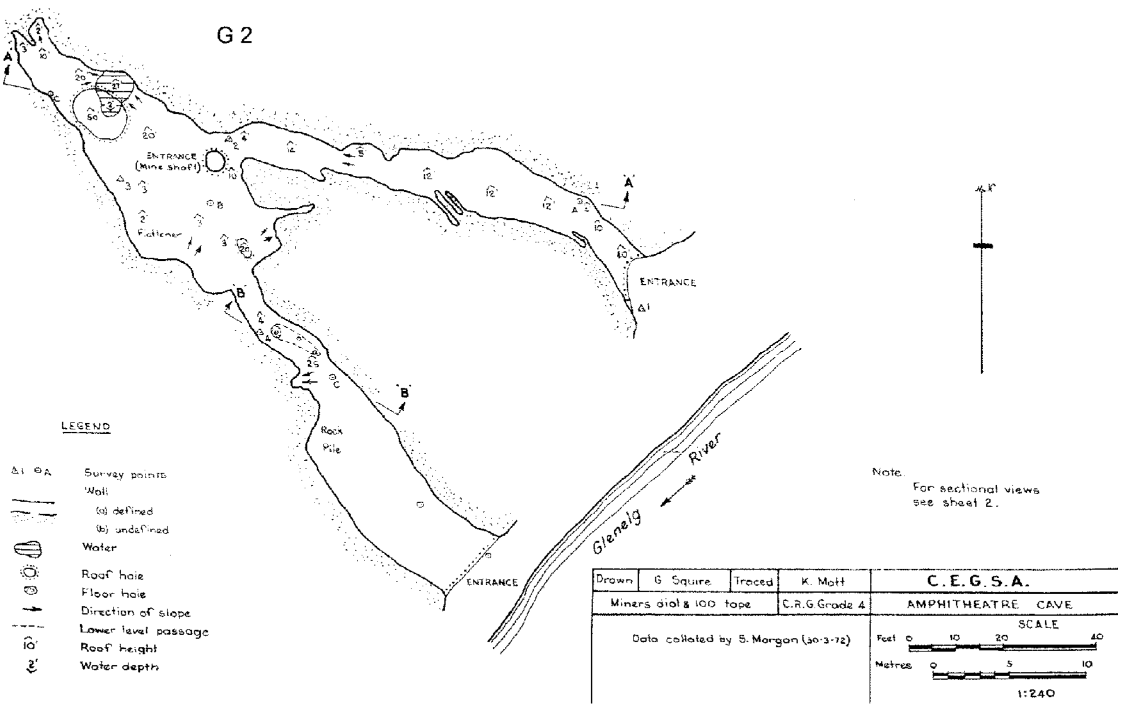

Figure 4 Map: Amphitheatre Cave (G 2) (after CEGSA map 3G2 CEG2, 1974)

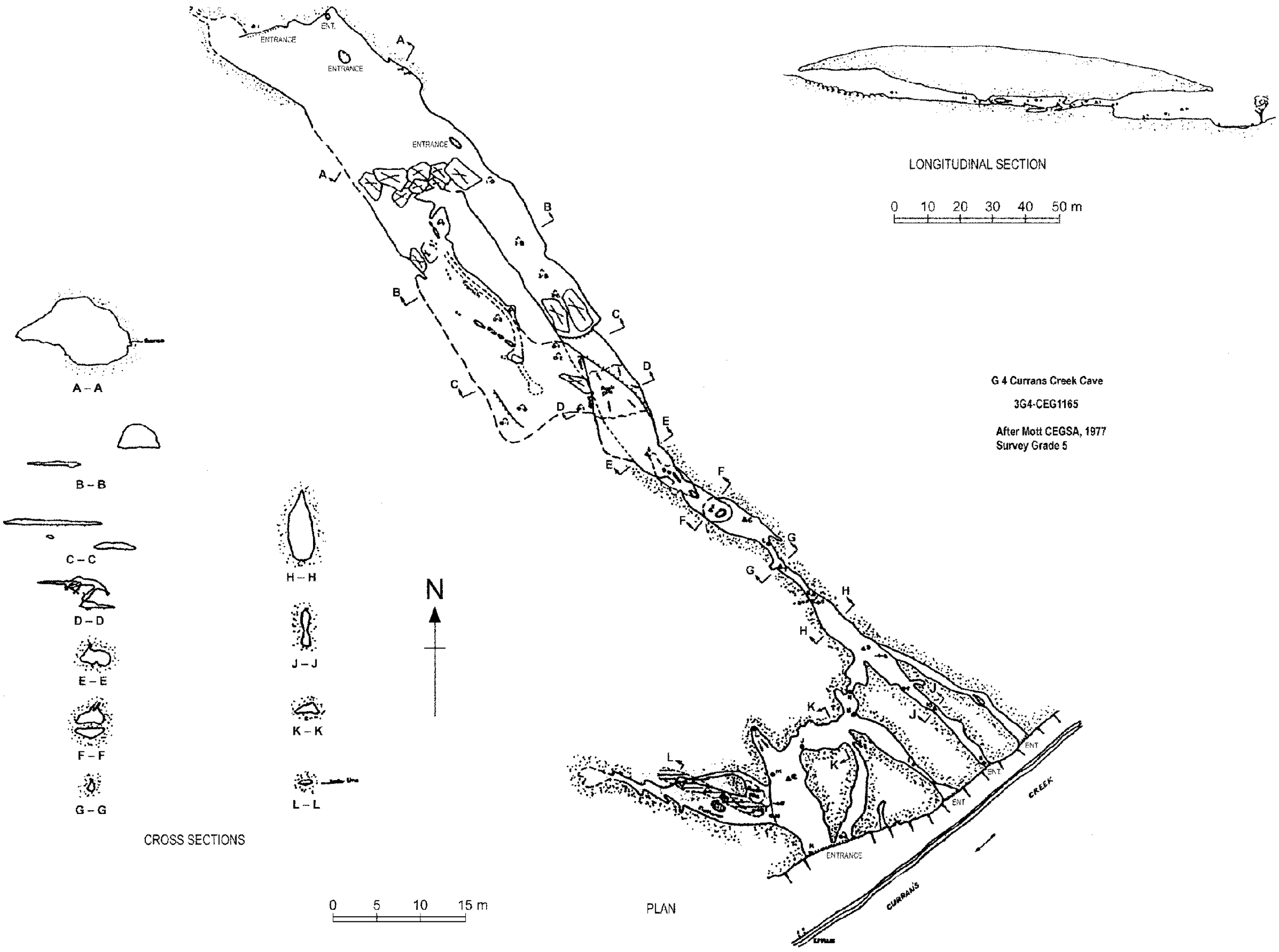

Figure 5 Map: Curran's Creek Cave (G 4) (after CEGSA map 3G4 CEG1, 1974)

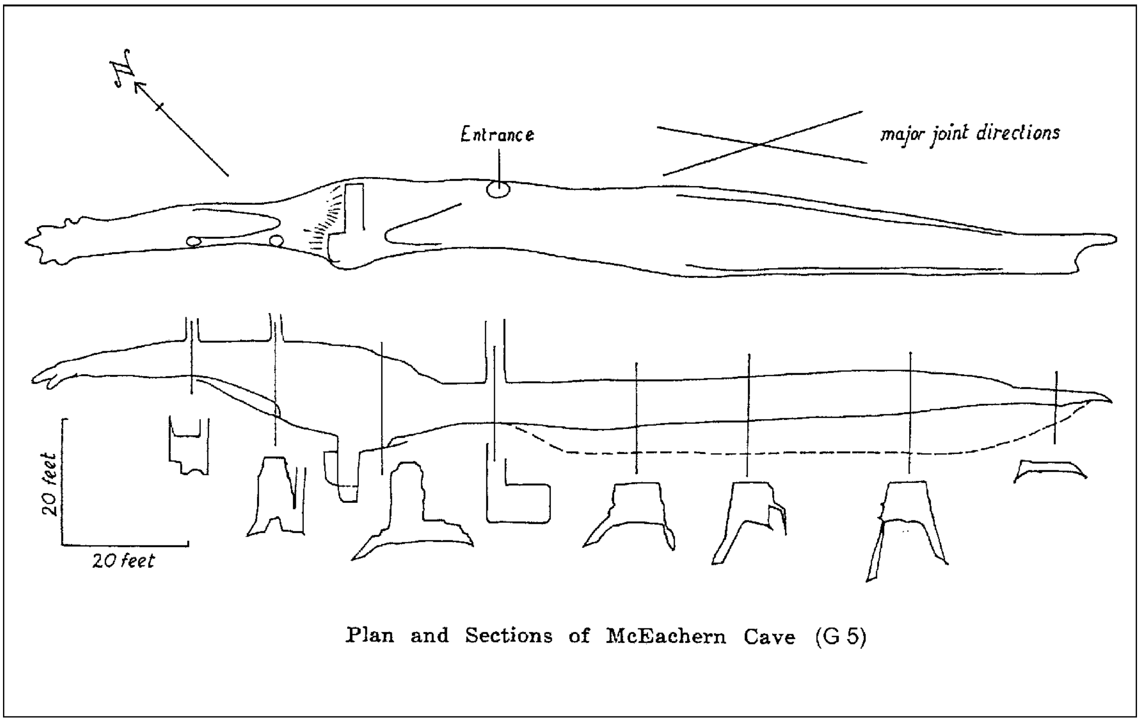

Figure 6 Map: McEachern's Cave (G 5) (after Ollier, 1964, M. Pierce, pers. comm., 1978)

The caves are predominantly simple, short single passages, i.e. single conduit caves. There are few multilevel or branchwork caves and no cave of the complexity of the maze caves observed at Naracoorte. Caves vary in length from a few metres, e.g. Hand Cave (L 3), to ~2 km (DD 4). Most cave passages are narrow, high rifts with near vertical walls, e.g. Princess Margaret Rose Tourist Cave (PMR) (G 6). Both phreatic and vadose passage shape are evident and many show evidence of phreatic initiation as either a subcircular or elliptical tube in the ceiling, e.g. PMR (G 6). However, vadose entrenchment occurs especially in the caves containing flowing streams. Surface weathering on the cave walls commonly obscures distinctive and diagnostic phreatic or vadose wall features. The influence of the predominant regional joint patterns on cave passage orientation is marked (Figures 7 & 8).

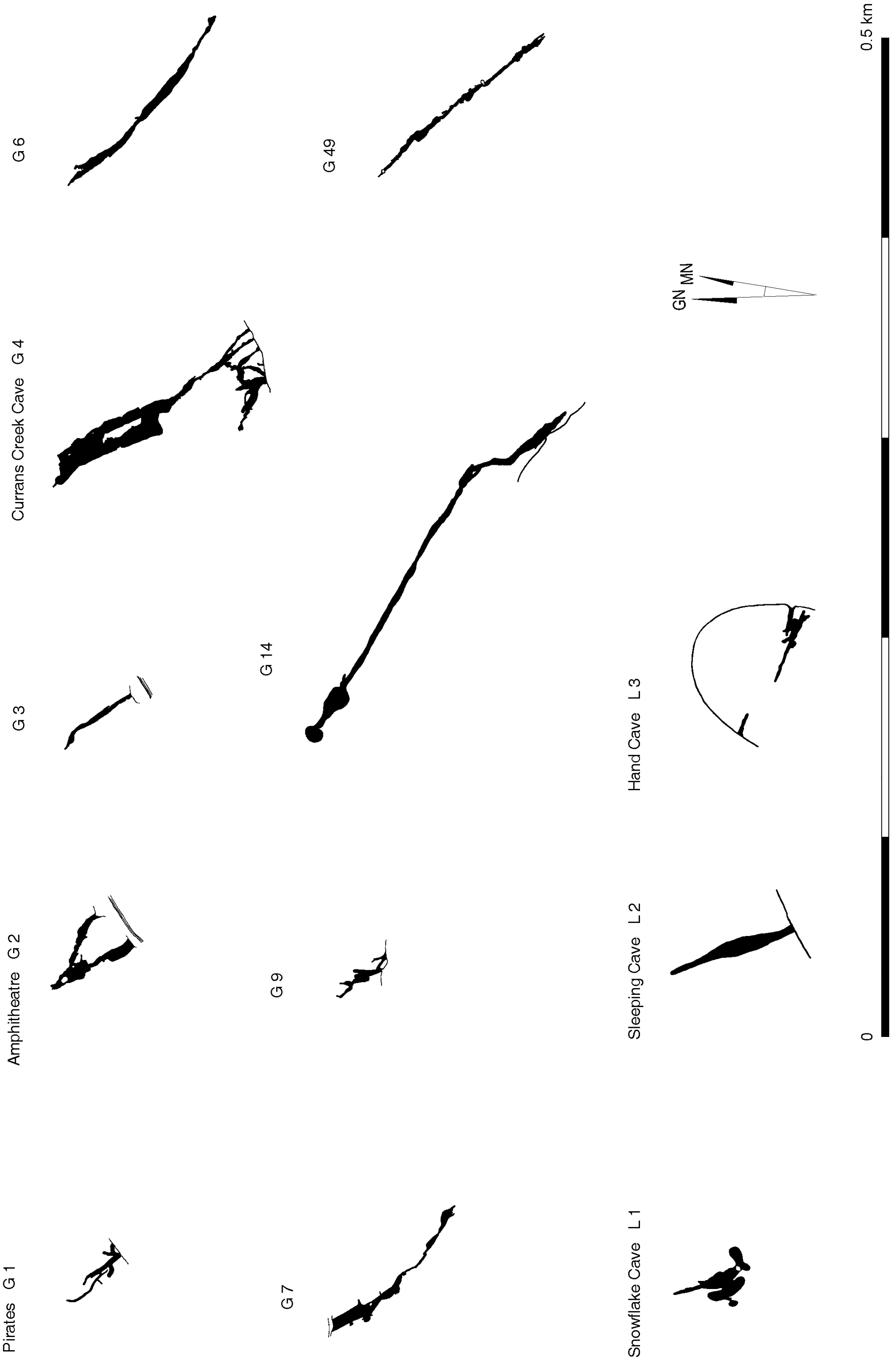

Figure 7: Cave orientations as passage outlines (after CEGSA and VSA maps)

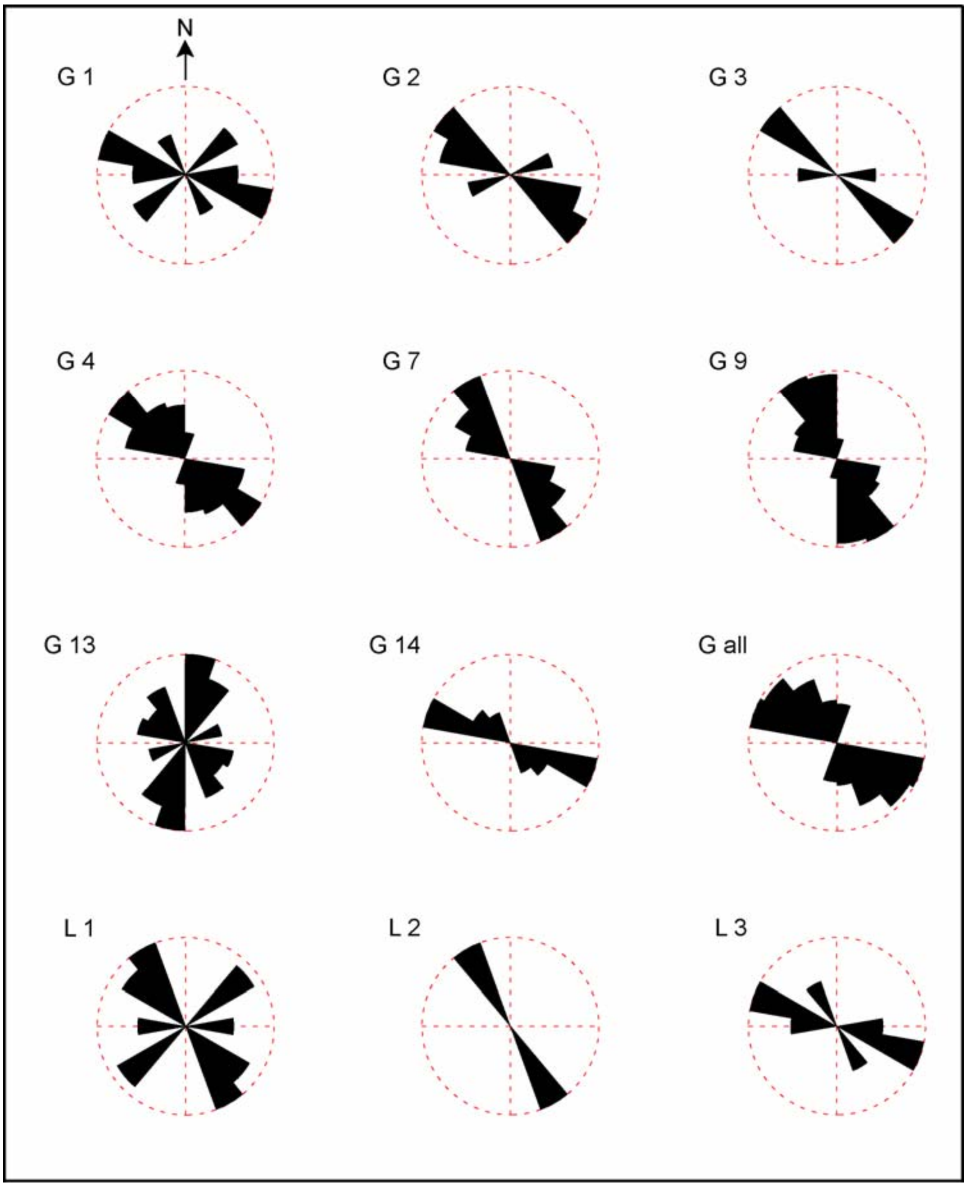

Figure 8: Passage Direction Roses, Glenelg River karst area (data from CEGSA and VSA maps)

Some passages have been modified by collapse, but the rubble piles found in many caves are generally small and collapse is not as important in cave modification as at Naracoorte.

Although a number of caves in the Glenelg River karst area contain water, this represents flowing streams and not groundwater pools.

Five entrance types are found: artificially modified entrances, e.g. PMR (G 6), solution pipes, e.g. G 10, collapse, e.g. DD 4 and horizontal "cave" type entrances, which can be subdivided into cave crawl and fissure types, e.g. DD 8 and McLennan's Punt Cave (G 14) respectively. In common with the Naracoorte area, many caves have more than one entrance and more than one entrance type. The most common entrance type is the fissure entrance especially along the river cliffs. These vary from tight vertical fissures to large fissures on the river cliffs. Vertical and smooth sided cylindrical tubes (solution pipes) penetrate from the surface and may intersect cave passages. They occur singly, e.g. G10 (Figure 9) or in multiples, e.g. Curran's Creek Cave (G 4), and typically have a thin, cemented rim, but are not associated with rhizomorphs. Solution pipes are characteristic of highly permeable limestones and are formed by focussed vertical flow of undersaturated meteoric water (Grimes, 2004; Lauritzen and Lundberg, 2000). In the Glenelg River karst area, solution tubes have always developed where Bridgewater Group aeolianites overlie the Gambier Limestone. They never act as the initial sink for a sinking stream. Solution pipes have a close association with fossil deposits, e.g. McEachern's Cave (G 5) and McEachern's Death Trap (G 49) as a significant pitfall linking the caves to the surface and enabling surface sediment and fauna to enter caves. Most have surface sediment at their base, often as sand cones. Solution pipes completely blocked with sediment are present in several caves, e.g. McEachern's Cave (G 5), McEachern's Death Trap (G 49), and these have probably been open entrances in the past.

Figure 9: Solution Pipe entrance, G 10 (Photo: R. Frank)

The main wall and ceiling solutional features present are horizontal grooves (notches), pendants and non-directional and large symmetrical scallops. Ceilings with bell holes and avens are found in specific caves only, e.g. DD 4, but are not a common feature in most caves in the area. The notches are either waterline notches or lithologically controlled and multiple waterline notches occurring in some caves, e.g. McEachern's Death Trap (G 49) probably correlate with base level stillstands during downcutting of the river, and may therefore correlate with particular sea levels (Kos, 2001), assuming minimal tectonic movement in the area over the Mid to Late Pleistocene period.

The caves in the Glenelg River karst area, except for DD 4, are significantly smaller, with more uniform passage dimensions, than those at Naracoorte and there are no large maze caves. The two branchwork caves, Amphitheatre Cave (G 2) and Curran's Creek Cave (G 4) are not distinctively different from the single conduit caves. Although collapse has modified passages in the Glenelg River karst area, the uniformity in passage dimensions is at least partly because there is no large collapse chambers. For example, the Princess Margaret Rose Tourist Cave (G 6) and G 3 contain an area of collapse but no large collapse passage occurs. The breakdown material in the caves has typically not been removed by solution. Caves in the Glenelg River karst area do not extend as far below the surface as at Naracoorte. There is only one cave over 20 m below the surface (DD 4), and this is also significantly longer than all other caves in the area; at 2000 m in length it is almost an order of magnitude longer than the next largest cave (Curran's Creek Cave, G 4) at 250 m in length.

Most caves do not contain extensive clastic sediments, as past or present streams have removed sediment relatively rapidly. However, extensive unconsolidated clastic sediments containing Pleistocene bone material are found in a few caves in the Glenelg River karst area: Amphitheatre Cave (G 2), McEachern's Cave (G 5), McEachern's Death Trap (G 49) (Baird, 1986; Hope and Wilkinson, 1982; Kos, 2001; Link, 1967; Wakefield, 1967).

Speleothem development in most caves is limited, with a few exceptions, e.g. Princess Margaret Rose Tourist Cave (G 6) and DD 4.

Cavern development and speleogenesis

The main process involved in cavern development in the Glenelg River karst area is dissolution. Solutional modification, especially vadose entrenchment, has continued to alter the caves after they were drained because underground streams are present in several. Collapse has occurred after the initial solutional development but it is significantly less important than at Naracoorte.

The caves were initially developed as phreatic conduits and later modification occurred as the river incised into the landscape in response to the lowering sea levels, the subsequent water table lowering and the draining of phreatic conduits. These passages may have been flooded again at times of high sea levels, and this high water level may be partially responsible for the solutional features on the walls of the caves. As they drained, the caves modified by entrenchment rather than collapse, so rift-shaped passages are common rather than collapse domes. Vadose canyons are present in those caves with streams, e.g. McLennan's Punt Cave (G 14). Other caves have been left as drained rifts, e.g. PMR (G 6). As the river has very few surface tributaries, these vadose fissure caves are significant contributing tributaries down stream from Moleside Creek. Many caves continue to contain at least seasonal flowing water, e.g. McLennan's Punt Cave (G 14).

Collapse features, including breakdown rock piles and domed ceilings, are less common in the area than at Naracoorte and no large collapse chambers of the dimensions found at Naracoorte occur. The vertical elliptical shape of the phreatic conduits is such that the removal of buoyancy support when the caves drained did not lead to collapse in most caves (E. L. White and W. B. White, 1969). In the few cases of major collapse, e.g. Curran's Creek Cave (G 4), it appears to be the result of beam failure of the roof.

The two isolated caves, McEachern's Cave (G 5) and McEachern's Death Trap (G 49), in the Bulley Ranges south of the river. show more collapse than other caves in the area indicating that the draining of the cave post dated significant cave development, as they are not current stream caves. Both have solution pipe entrances and contain significant Late Pleistocene fossil deposits (Kos, 2001; Wakefield, 1969).

Landscape History

The Gambier Limestone accumulated in the near-shore shallow water Gambier Embayment of the Otway Basin during the Oligocene and Miocene (Holdgate and Gallagher, 2003). Coastal barrier conditions occurred across southeastern Australia (Warne, 2002). The karst landscape developed in several stages which are presented graphically in Figure 10.

In the Glenelg River karst area the caves are significantly less complex than at Naracoorte. All but three caves are single conduits and there are no maze caves. The single conduit caves are mostly linear and less than 100 m in length. The two main karst areas at Glenelg River formed at different times. At Drik Drik karstification occurred at similar times to the formation of karst at Naracoorte (between 1.1 Ma and 400 ka), whereas the caves along the Glenelg River lower reaches and the Bulley Ranges developed no earlier than the 400 ka (□□^{18}O stage 11) stillstand.

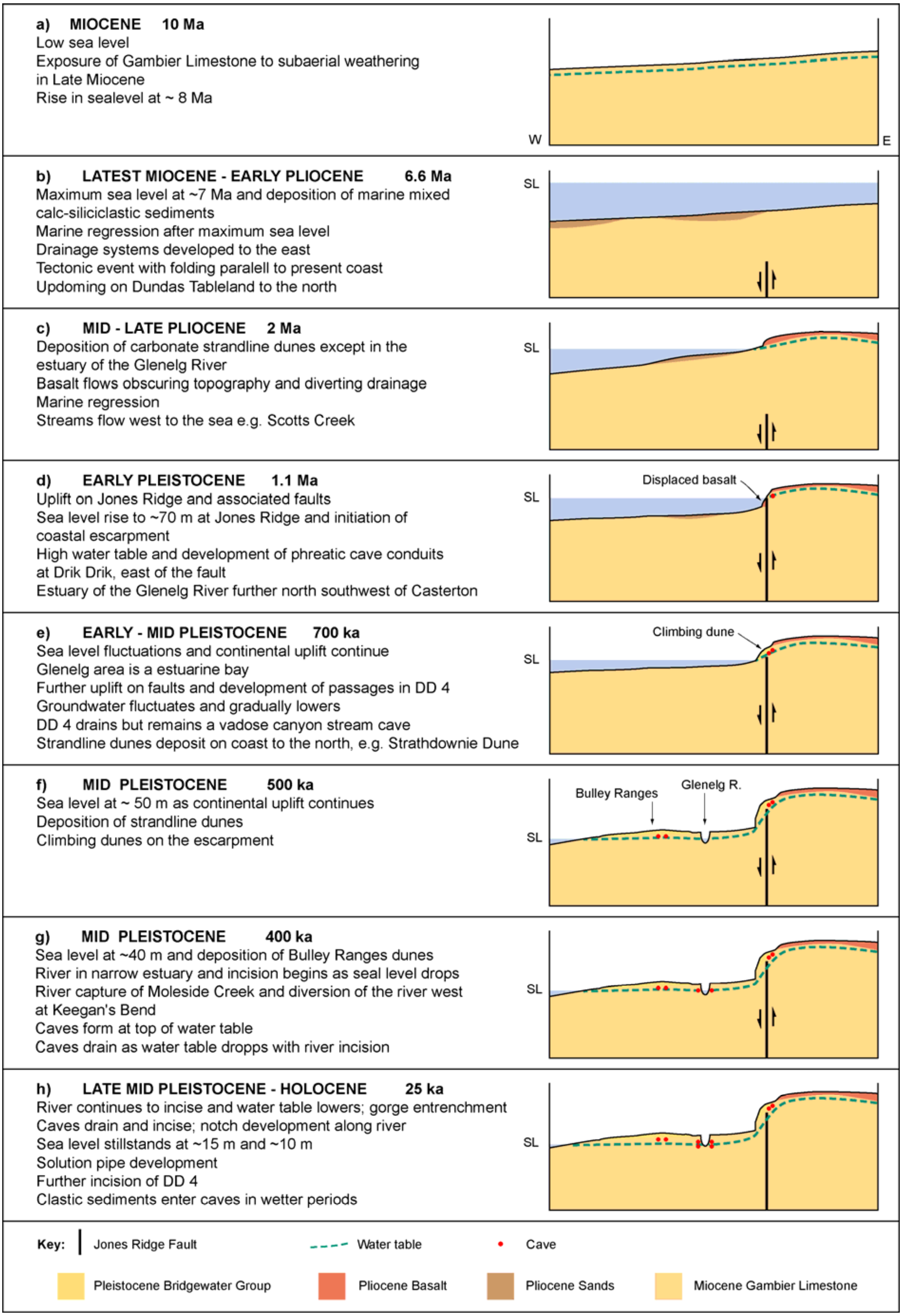

Figure 10: Landscape evolution stages, Glenelg River karst area

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