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Geomorphology of karst areas on Kangaroo Island, South Australia



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Abstract

The west and southern coasts of Kangaroo Island are blanketed by a sequence of dune limestones of Pleistocene age. The formation of the dune limestone along the coast impeded the central plateau's pre-existing drainage and led to the development of a shallow lagoon at Kelly Hill, along the contact with the limestone. It is likely that a process of mixing corrosion was involved, with preferential cave development at the interface of the lagoon water and rainwater infiltrating down through the limestone. This resulted in a maze of passages forming at the water table, seen most easily today in Kelly Hill Cave. Subsequently, valley incision and slight uplift on the south coast drained the lagoon, and an ongoing process of collapse ensued in the caves. The loss of hydraulic support for the cave roofs resulted in a series of tensional arches in which the cave roofs became too wide to support their own weight. This process continued until the caves formed structurally stable arches, some of which open to the surface as dolines. This unusual process of cave development is primarily controlled by the relatively soft, porous and also permeable nature of the limestone and its lack of jointing.

INTRODUCTION

Kangaroo Island is a continental island located 14 km across the Backstairs Passage from Cape Jervis on the Fleurieu Peninsula of South Australia (Figure 1). The island is approximately 145 km east to west and 60 km north to south, with a land area of approximately 4400 km². It is a geologically diverse environment with rocks ranging in age from the Palaeozoic through the Mesozoic and Cainozoic. Roughly 18% of the island is karst, principally on the western and southern coasts and extending inland up to 5 km. Multiple episodes of coastal dune migration during Pleistocene high sea stands resulted in the formation of dune limestones or aeolian calcarenites, which achieve a maximum height of 65 m above present sea level at Cape Bouguer. Karst features are well developed including major and minor caves, sea caves and dolines. Following extensive bushfires in early 2020, during which just under 50% of the island (approximately 211,000 ha) was burnt, a project was established under the South Australian Speleological Council (SASC) to relocate, document and map caves on Kangaroo Island. To date 100 caves have been relocated and 162 new caves or karst features found. This paper is based on the results of the project to 2025.

The most extensive karst area forms the Kelly Hill Conservation Park on the southwest coast of the island. Caves have been known in this area since 1885, with the area becoming a reserve under the Flora and Fauna Board in 1926. Later in the same year, guided tours of the Midnight Cave commenced by the light of hand-held candles. Exploration, surveying and mapping of the caves on Kangaroo Island by the Cave Exploration Group of South Australia Inc. (CEGSA) has been ongoing since 1955, and electric lighting was installed in Kelly Hill Cave (K1) in 1956. The karst area is now under the control of the National Parks and Wildlife Service South Australia (NPWS SA). Extensive bushfires in early 2020 burnt just under 50% of the island (approximately 2110 km²). The burnt area included almost all of Kelly Hill Conservation Park and Flinders Chase National Park, which between them host the majority of the island's karst. Fire intensities were very high resulting in widespread spalling of limestone outcrops to a depth of 2-5 cm, baking of soil and washing of soil and charcoal into

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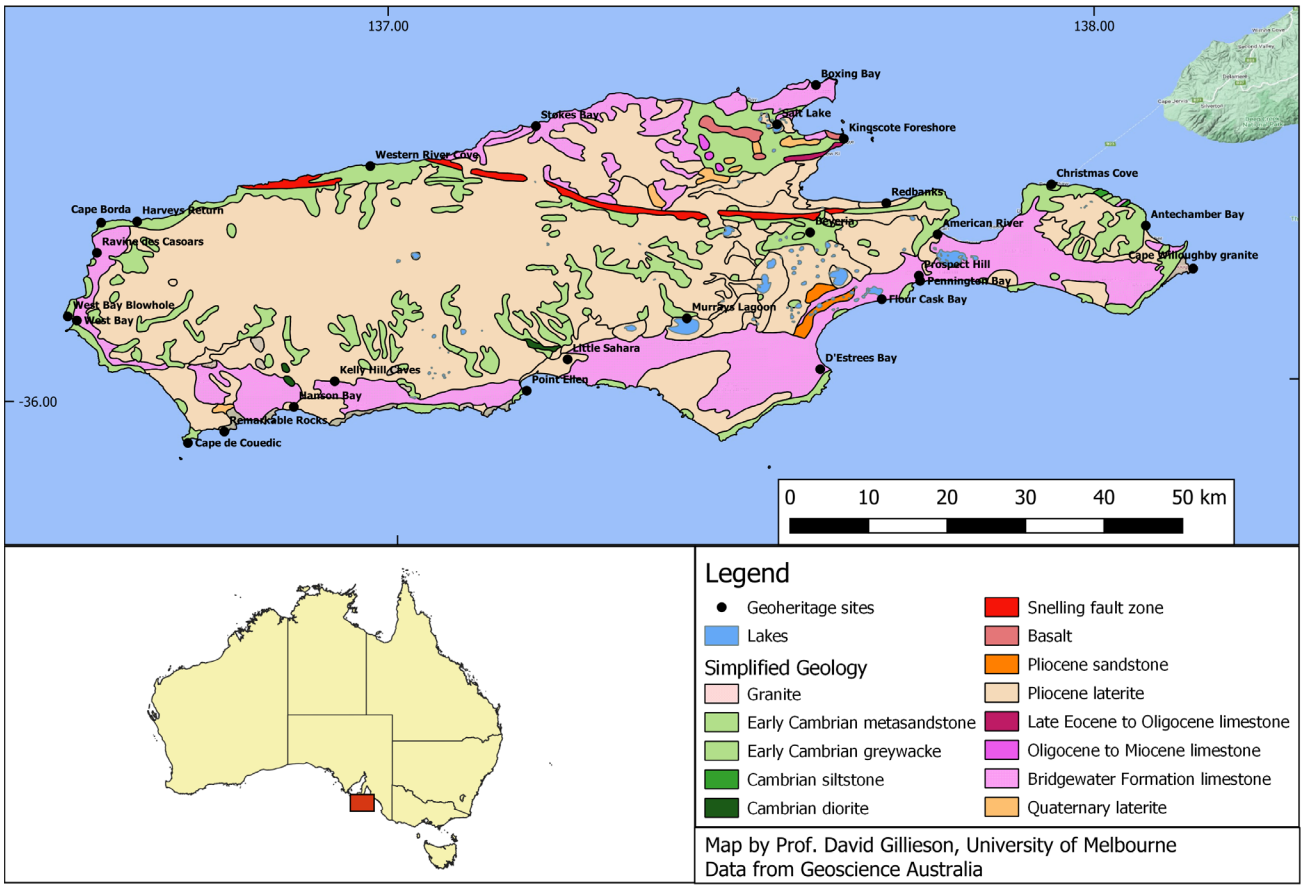


Figure 1. Simplified geology of Kangaroo Island, South Australia, showing existing geoheritage sites. Map in QGIS by David Gillieson, data from Geoscience Australia.

dolines. Sediment and charcoal washing downslope across the main road diverted water flows and partially blocked three main water sink points along the northern side of Kelly Hill. As part of the post-fire recovery efforts, a project was established under the South Australian Speleological Council (SASC) – with the assistance of the Cave Exploration Group (SA), Flinders University Speleological Society (FUSSI) and Scout Cave Group (SCG) – to relocate, document and map caves on Kangaroo Island. A Friends of the Karst group was formed in 2021, approved and funded under the SA Parks volunteer scheme to locate, document and map both known and new caves in the Kelly Hill karst and elsewhere on the island.

This paper uses data from these recent surveys to refine knowledge of the geomorphology and hydrology of the Kangaroo Island karst.

Geological Overview of Kangaroo Island

The island is structurally an extension of the Fleurieu Peninsula on the mainland, with arcuate faults and complex fold structures (Figure 1). Cambrian metasediments form the basement of the island, and are exposed at the coast. In the centre of the island, a Miocene to Pliocene lateritic plateau has formed on the Cambrian rocks and reaches an elevation of 265 m in the north-west and declines to 100 m elevation in the south-east.

The central plateau is the dominant landform of the island. This plateau has been tilted and dissected, with remnants occurring over much of the island, including on the eastern Dudley Peninsula. The Cambrian sediments are exposed in the valleys draining this lateritic plateau to the north and south. Around the periphery of the plateau, denudation has resulted in a landscape developed on resistant Cambrian metasediments with thin soils. Significant uplift occurred during the Quaternary, resulting in sea cliffs 150 to 200 m high along the north coast of the island, and 50 to 60 m high along the south and west coasts of the island. The southern and western coasts of the island are mantled by aeolian calcarenites or dune limestones which occupy about 16% of the island and are of Pliocene to late Pleistocene age (Belperio 1995; Gillieson 2023).

The Kangaroo Island dune limestones form part of a widespread sequence of late Pliocene and Pleistocene dune limestones that extend along the southern coast of Australia from Margaret River in Western Australia to Warnambool in western Victoria. Although these areas share many similarities in their geomorphology and hydrology, the Kangaroo Island limestones have been subject to late Quaternary uplift, comparable with the southern coast of Victoria but unusual in the broader context of coastal karst in Australia.

The dune limestone or aeolian calcarenite is made up of skeletal carbonate remains resulting from the breakdown of marine invertebrates, such as molluscs, bryozoans, echinoids, foraminifera and coralline algae. These deposits of dune limestone relate to phases of high sea level over the last two million years when coastal dunes were mobilised and then stabilised by vegetation. Thus, at the top of each dune sequence there are often relict soil profiles or palaeosols, formed during periods of landscape stability and probably at times of low sea levels and reduced sand supply. In places there are relict beach deposits interbedded with the dunes, and there are at least four relict soil profiles visible. The dune limestones on Kangaroo Island have been mapped as equivalents of the Bridgewater Formation in Western Victoria, and a number of age determinations have been made which broadly confirm this. The early Pleistocene Cape Hart limestone, which is well lithified, has an associated strontium isotope age of 1.8 million years, while the lower units of the dune limestone have produced strontium isotope ages of 1.18 and 1.2 million years (Belperio 1995). Deposition of the aeolianite successions has occurred since at least latest Early Pleistocene time. At Kelly Hill Caves, an amino acid racemisation age of 835 ka has been obtained on dune limestone and an optically stimulated luminescence date on included quartz sand grains (OSL) returned a date of 1.3 million years (McDowell and others 2013). The Middle Pleistocene limestone has an associated strontium isotope age of 520 ka (Belperio 1995). A trace fossil site at Boar Beach on the Dudley Peninsula has associated OSL dates of 135 and 137 ka (Lachlan 2011, Camens and others 2017).

For comparison, the deposition of the aeolianite/palaeosoil cycles represented by the Bridgewater Formation members reflects the alternating glacial/interglacial climates accompanied by changing sea level over at least the past 500 ka (Lipar & Webb 2015). Their study shows that aeolian carbonate sand deposition on Cape Bridgewater occurred during three interglacial periods: MIS 7 (243 – 191 ka), 9 (337 – 300 ka) and 11 (424 – 374 ka). More recently (Weij and others 2022) uranium series dating of speleothems from the Naracoorte caves support an age of at least 1.34 My for the Bridgewater Formation.

Surface Geomorphology of the Kelly Hill Karst

The dune limestones of Kangaroo Island provide a good example of syngenetic karst, a term coined by Jennings (1968) for karst features and caves that form within a soft porous sediment at the same time as it is being cemented into a rock. Thus, lithogenesis and speleogenesis are essentially concurrent (Grimes 2006). Syngenetic karst is widespread in the Quaternary dune limestones of southern Australia and South Africa (Marker & Sweeting 1983). In recently deposited calcareous dunes, percolating rainwater gradually converts unconsolidated sand to limestone by dissolution and redeposition of calcium carbonate. This process is enhanced by both bacterial and fungal action in the root zone of vegetation stabilising the dunes (Warren 1983). Within Pleistocene dunes and especially within calcrete zones, sand grains are often coated with a rind or envelope of micritic calcite. At the base of the developing soil profile, carbonate is precipitated to form a calcrete or hardpan, which may be exposed following erosion. Beneath the calcrete or hardpan, shallow caves may form. These are typically short horizontal mazes of low, wide interconnected chambers with widespread collapse. At depths in the calcareous dune, there may be buried palaeosols and also calcretes which indicate former water tables.

Many of the Kelly Hill caves are accessed by bedrock pipes of dissolutional origin. These vary in diameter from 1 to 2 m and up to 10 m deep. According to Lipar and others (2021), these voids are formed by focussed flow in the epikarst zone of porous calcareous rocks with medium to high matrix porosity. Most occur in eogenetic rocks, particularly in Quaternary calcarenites, but some pipes have also been reported in Miocene-Pliocene and Cretaceous chalk.

Solution of limestone is enhanced by mixing corrosion, which can occur where two water bodies differentially saturated in calcium carbonate mix. There are at least two situations where this

occurs in the Kangaroo Island karst. The first is where percolation water that has passed through the epikarst meets the water table, which is often controlled by the level of nearby swampy plains. This interface is a zone of enhanced carbonate solution. Secondly, groundwater moving laterally at the coast forms a freshwater lens overlying seawater resulting in mixing corrosion. This can result in mazelike flank margin caves. These have a characteristic form with interconnected mixing chambers that attenuate as one moves away from the coast.

The main driver for cave development in the Kelly Hill ridge has been water flowing off deeply weathered Cambrian metasediments to the north, in the catchment of the South West River (Figure 2). There are several water sink points along the northern side of the Kelly Hill ridge, and these are today at altitudes between 18 and 19.5 m above sea level (Figure 3). Water sinking into the limestone would have dissolved the extensive network of passages forming a maze with solutional spongework. The base level for these caves would have been controlled by the contact with the underlying Cambrian metasandstone, which effectively forms an aquiclude below the limestone. Water flows down gradient to the coast and is also fed by active water sinks on the margins of the Grassdale Lagoon at 4.5 m above sea level. This karst water emerges at the base of a bluff 1 km upstream of the coast on the South West River, as well as from seepage springs at the base of the sea cliffs and, periodically, also as freshwater upwellings reported off the coast by fishermen (Michael Bald and Peter Davis, pers. comm.)

Surface exploration taking advantage of the reduced vegetation cover after bushfires has clarified a number of aspects of the geomorphology of Kelly Hill Conservation Park. The flat area to the north of the ridge is the remnant of a marginal lagoon traversed by stream channels from the north. At the eastern end of the karst ridge the underlying Cambrian metasandstone is exposed at the surface, marking the limit of the dune limestone. In the same location there are unloading joints in the limestone, up to 50 m long and 6 m deep, which are a consequence of the erosion of the valley leading to the Southwest River. The schematic cross-section (Figure 4) is a first attempt to understand the geomorphology and hydrology of the Kelly Hill area, including the Cape Bouguer karst to the south. Height data are derived from the 1 m resolution LIDAR data flown by AAM Hatch in 2020 and supplied by the SA Department of Environment and Water. Additional high resolution LIDAR data

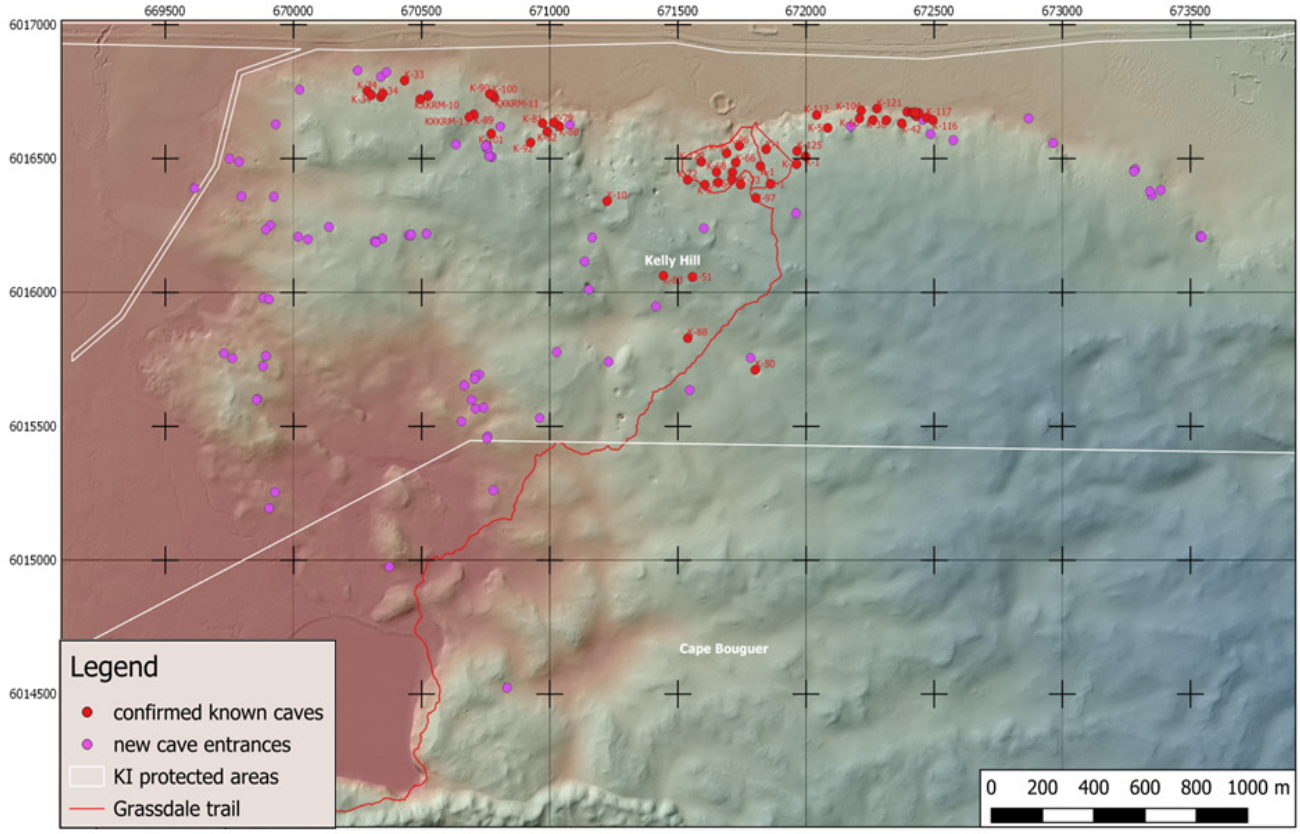


Figure 2. LIDAR terrain model showing known dolines and cave entrances on Kelly Hill as at April 2024. Data from AAM Hatch Pty Ltd, courtesy of South Australian Dept. for Environment and Water.

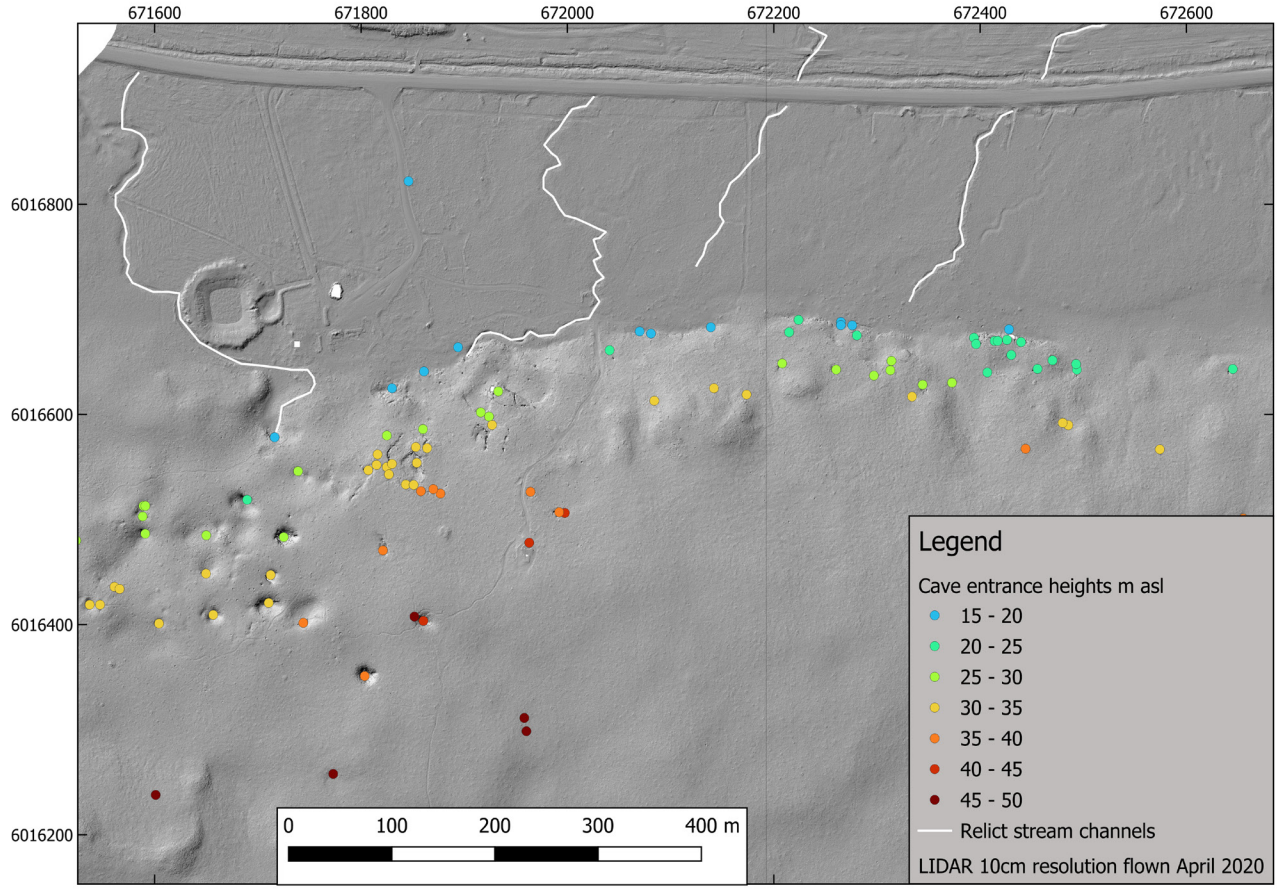


Figure 3. Water inflow points on the northern side of Kelly Hill, with entrance heights from SASC surveys. LIDAR data flown in April 2020 by Jorg Hacker, Airborne Research Australia.

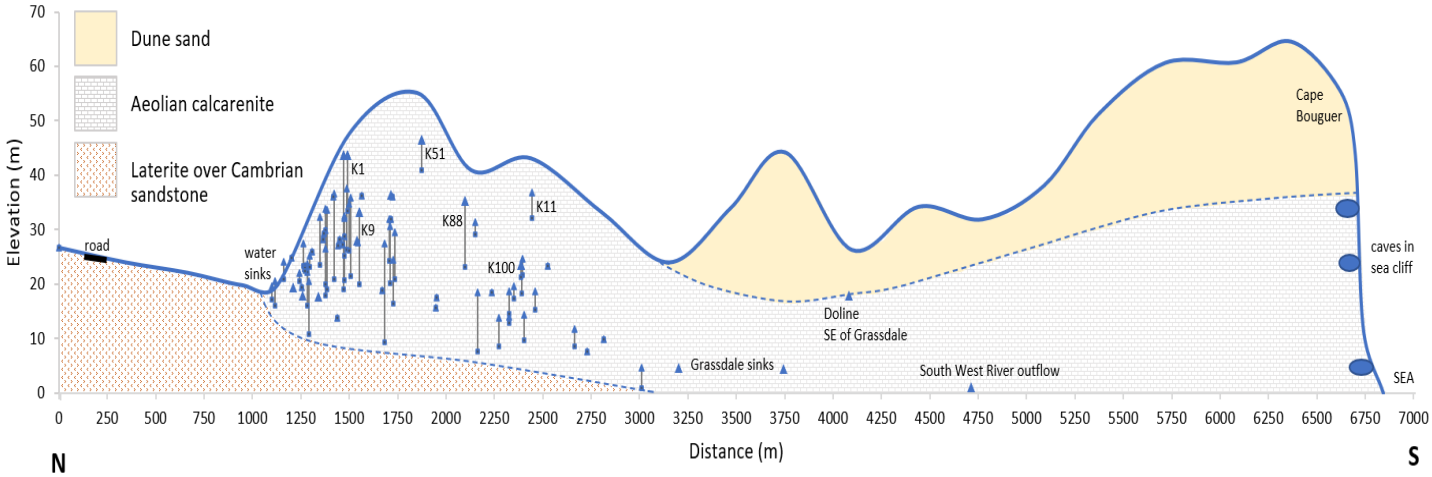


Figure 4. North-south geomorphological cross-section through the Kelly Hill karst, with vertical ranges of mapped caves.

was flown by Jorg Hacker of Airborne Research Australia in April 2020 and December 2022. The cave locations and height range data come from the Friends of Parks Kelly Hill Caves group of the South Australian Speleological Council.

Cave development at Kelly Hill

On the high ridge to the south of the Kelly Hill Cave tourist site (K1) is an extensive deposit of lateritic gravels (Figure 5) which may have been washed from the ridge to the north prior to the incision of the South West River, which lies just to the west. This would suggest that the initial cave development may have occurred by water sinking at a much higher level (40-45 m asl) in the

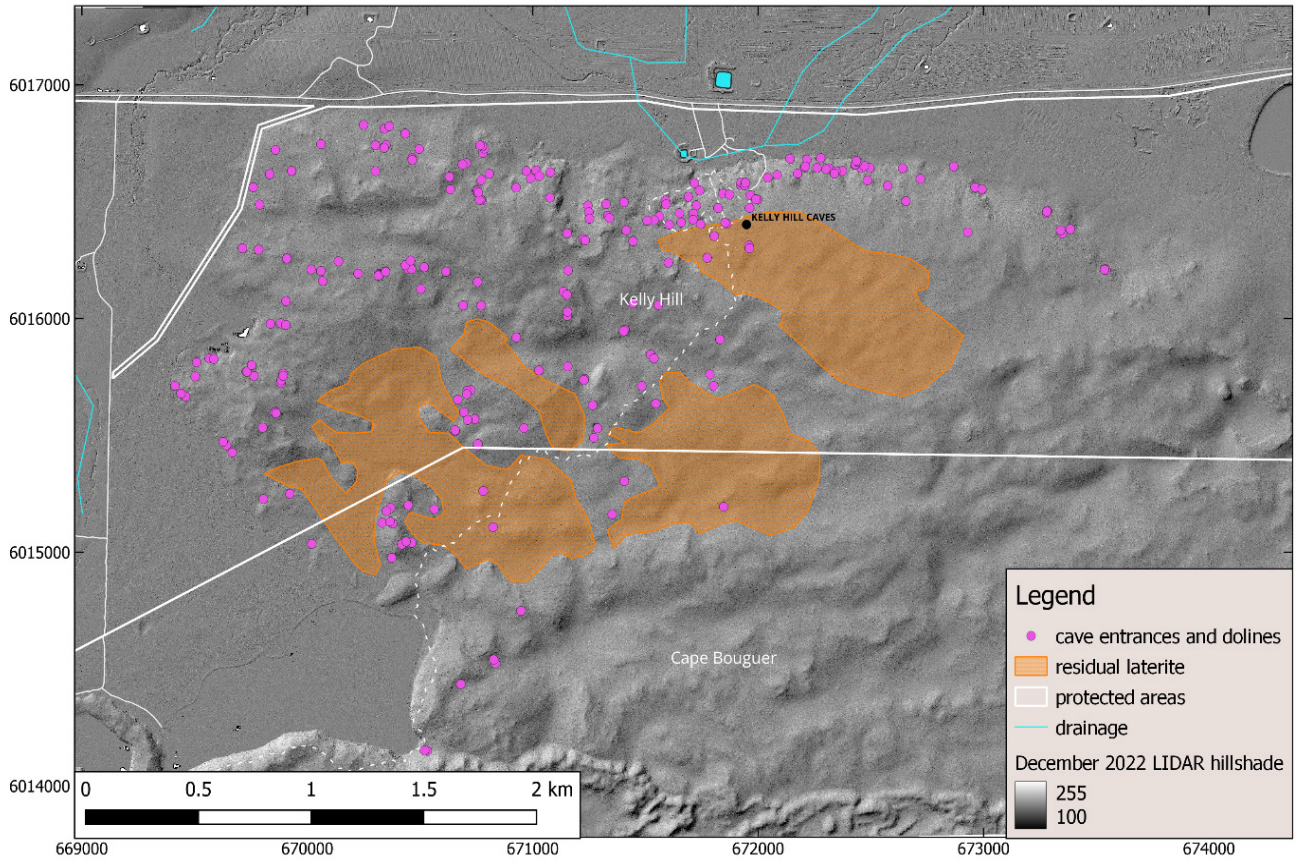


Figure 5. LIDAR hillshade image of the Kelly Hill karst, with extent of residual laterite capping and mapped cave entrances and dolines.

landscape than it does today. Following uplift and lowering of the water table, collapse domes formed in the relatively weak and unconsolidated dune limestones. To the south of the Kelly Hill ridge, near Frosted Floor Cave K11, the limestone is overlain by Holocene dune sand of variable thickness which reaches a maximum height of 65 m at Cape Bouguer. There are several large enclosed depressions to the south-east of Grassdale Lagoon, and water sinking there is also likely to drain to springs at the coast. These have been briefly investigated but no enterable caves have yet been found.

The majority of mapped caves on Kelly Hill have a vertical range of 4-6 m, while a secondary group has a range of 10-12 m (Figure 6a). The few caves with a vertical range from 16 to 20 m include K1 (Kelly Hill Cave), K11 (Frosted Floor) and K34 (New Years Day Cave), all of which are located high on the Kelly Hill ridge. The heights of cave entrances in the Kelly Hill ridge appear to fall into four groups, with the highest entrances between 40 and 47 m above sea level, a group between 32 and 36 m, and another group on the western side of the ridge whose entrances are around 24-28 m above sea level (Figure 6b).

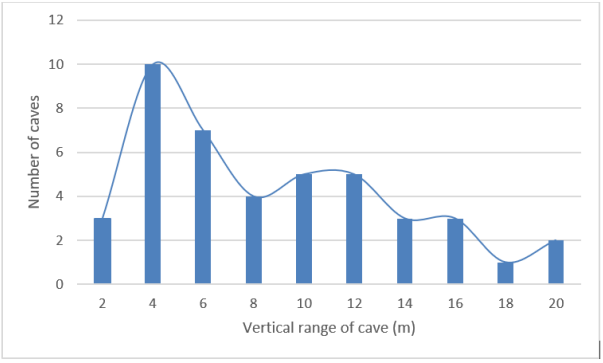


Figure 6. (a) Histogram of vertical range of individual caves on Kelly Hill.

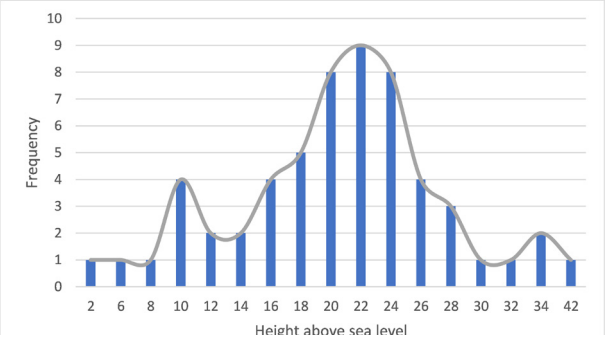


Figure 6. (b) Histogram of lowest point in caves above mean sea level.

In the sea cliffs at Cape Bouguer and elsewhere, there are flank margin caves developed at altitudes of 32-35, 20-25 and 6 m above sea level (Figure 4). The higher caves are most likely to be relict features as the result of uplift over the last two million years. The caves at +6 m relate to the Last Interglacial sea level (MIS 5), some 125 ka. There are several sea caves at this level along the coast between Cape Bouguer and the Stun'sail Boom River mouth. It is interesting that the base levels of caves in the Kelly Hill ridge appear to approximately correlate with both the 32-35 m and 20-25 m cave levels.

Subsequently, valley incision and uplift on the south coast drained the lagoon, and an ongoing process of collapse ensued in the caves. The loss of hydraulic support for the cave roofs resulted in a series of tensional arches (Hill 1984) in which the cave roofs became too wide to support their own weight. This process continued until they formed structurally stable arches, or they opened to the surface as dolines (Hill 1984). This process of cave development is primarily controlled by the soft, porous nature of the limestone and its lack of jointing. Hill's pioneering work has now been applied to many caves formed in dune limestone in southern Australia.

In the Kelly Hill caves, the cross sections through the main passages are remarkably consistent, with tensional collapse domes linked by short rift passages (Figure 7). The domes are all between 15 and 20 m across and the rift-like sidewalls are generally choked with collapse debris. Subsequent to the collapse, there has been extensive speleothem deposition and the varied orientations of stalagmites would suggest that the sinking or rafting down of limestone blocks on the floor is ongoing. In many places, the collapse domes have breached to the surface to produce sinkholes while in other places solution pipes provide access to the domes.

Sea caves and coastal karst

The extensive dune limestones on Kangaroo Island form sea cliffs up to 60m high and their upper surfaces are punctuated by dolines. These fall into several types: small collapse dolines leading to shallow caves, solution dolines with pipes, broad solution dolines partially filled with sand and flank margin caves breached by coastal cliff retreat.

Admirals Arch at Cape du Couedic

This iconic site is a sea cave in Pleistocene dune limestone resting unconformably on sloping Cambrian metasandstone (Figure 8). Formation of

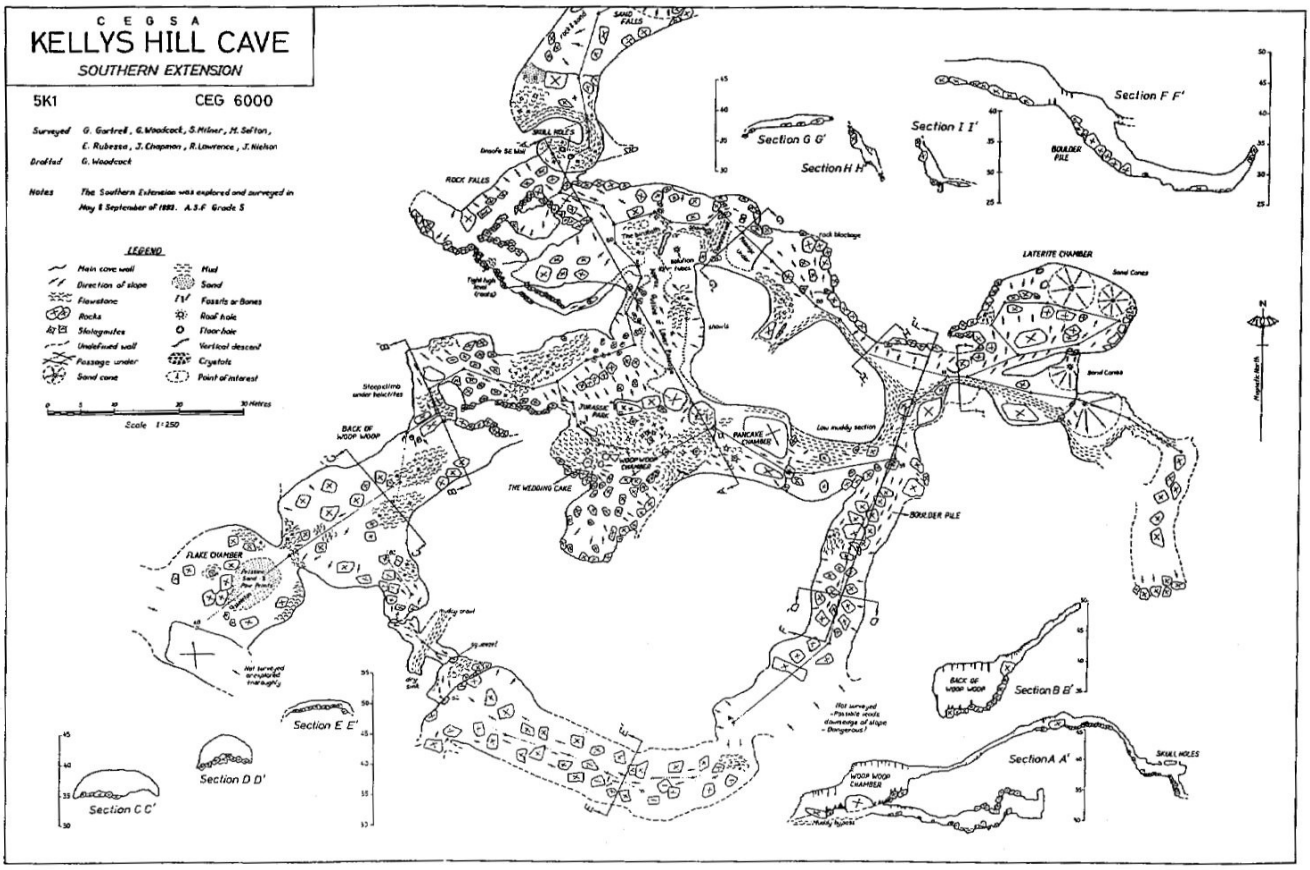


Figure 7. Map of K1 Kelly Hill Cave southern extension, courtesy of CEGSA.



Figure 8. Admirals Arch: Pleistocene dune limestone overlying Cambrian sandstone

the Arch was not solely due to wave action. Initially a flank margin cave formed when sea level was higher, possibly around 125,000 years ago. At that time with sea level 3-5 m higher, solution of the limestone occurred at the interface between fresh and salt water where mixing corrosion would occur. There are solution pockets in the north wall of the arch which would have formed below the water table, and the original floor of the Arch is preserved as a level bench of dune limestone on the north side as well. That floor has been mostly stripped away by modern wave action ramping up the sloping sandstone platforms. Thus Admirals Arch appears to be a breached flank margin cave, which has been modified by wave action during higher sea levels. There are numerous outside stalactites and rhizomorphs in the roof of the Arch, which is partly supported by a hardened calcrete layer formed on the upper surface of the aeolianite. This site and neighbouring Weirs Cove (Figure 9) show flank margin caves at several levels which may be related to Pleistocene uplift. Other flank margin caves are visible on the nearer of the two Casuarina Islets (The Brothers) facing Admirals Arch. Remnant stalactites and stalagmites can be seen as well, suggesting these caves were sealed in the past prior to breaching by wave action. These appear quite different to the more porous exterior stalactites and flowstones (äußerer stalaktiten) often seen in limestone cliffs.

Ravine des Casoars

This is a deeply incised valley running inland from the coast 5 km south of Cape Borda, with several flank margin caves. The V-shaped valley ends in a broad beach, minor backing dunes and a narrow coastal lagoon. The valley fill is dominated by marine-sourced sands of Holocene age from the adjacent narrow marine shelf; little sediment appears to have been derived from erosion of the surrounding plateau surface. The southern valley side slope is covered by climbing dunes, which extend up to 100 m asl, a result of the strong westerly onshore winds.

The Ravine was first named by the French explorer Nicholas Baudin in 1802, who thought the now-extinct dwarf emus there were cassowaries. It was also home to a group of shipwrecked French sailors in 1815, who left an engraving on a flat rock



Figure 9. Weirs Cove, showing flank margin caves at several levels up to 35 m above present sea level.

within the cave. The present entrance of Baudins Cave K5 (Figure 10) is at sea level and the cave is best visited at low tide. The seaward cave has two entrances linked by a flat sandy floor which is awash at high tide (Figure 11). At low tide a short daylight passage leads around the headland to a pocket beach under calcarenite cliffs. The cave has two collapse domes linked by a short passage, with abundant speleothems. The landward cave has a well decorated entrance zone and a steep rockfall and a small chamber at the rear. There are several other flank margin caves in the north wall of the valley near this cave, and some large dolines on the plateau to the north and south of it.

Cape Dutton sea cave

This site is located on the north coast of the island, 7 km to the west of Stokes Bay. A thick sequence of dune limestone overlies Cambrian sandstones, and is exposed in cliffs 50 m high. The cave is located at the contact of the sandstone and limestone, and a horizontal tunnel 80 m long has a floor of sand and rounded boulders (Figure 12). Its entrance is 5-6 m above present sea level, which would suggest that it relates to the Last Interglacial sea level (MIS 5). There are several marine terraces, gravel and cobble deposits at this level at Admirals Arch and at Kingscote along the coast of Kangaroo Island. Below the entrance windblown sand forms a ramp leading to the entrance.

The cave is located on private property and is reached by climbing down a very steep ridge to the sea. There is a large sea eagle nest directly above the cave entrance which has been continuously occupied for at least 40 years, and should not be disturbed.

Vennachar Point and West Bay

At the extreme western end of the island, West Bay is a deep harbour regularly used by yachts. To the north of the bay is Vennachar Point, the site of the 1905 wreck of the Loch Vennachar, wool clipper. Wreckage from this ship was spread along the southwest and south coasts of the island; there were no survivors. In the days of sail, ships frequently came to grief on this cliffed coast, which is fully exposed to westerly winds and the Southern Ocean. To the north of the point are deep gulches or geos cut into the Cambrian sandstone (Figure 13),

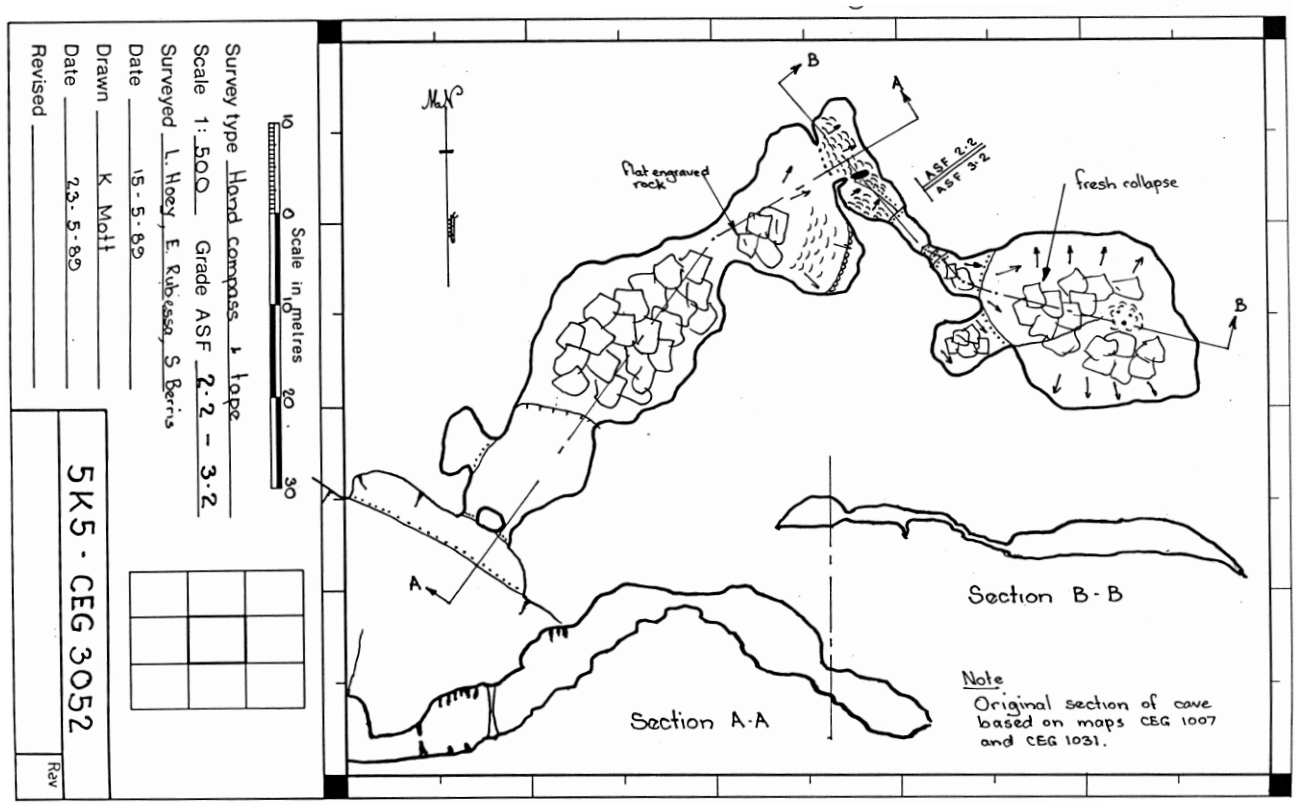


Figure 10. Map of K5 cave at Ravine des Casoars, courtesy of Kevin Mott and CEGSA.



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Figure 11. Ravine des Casoars Cave. (a) View from the seaward cave entrance. (b) Flank margin cave upstream of caves. (c) Entrance chamber and inner collapse dome. (d) Solution slot due to mixing corrosion at interface between fresh and salt water.



Figure 12. (a) Sea cliff in dune limestone overlying Cambrian sandstone at Cape Dutton. (b) Sea cave at contact of sandstone and dune limestone, ceiling height 3 m; the cave extends 80 m into the cliff.



Figure 13. (a) Aerial image of geos and a deep shaft north of Vennachar Point. Image sourced from Location SA viewer http://location.sa.gov.au/viewer/ (b) Large geo at lower edge of aerial image.

and capped with Pleistocene dune limestone. About 1.5 km north of West Bay is the Vennachar Point blowhole (Figure 14), which can be descended for 35 m and links to the sea by a narrow cleft with a boulder beach. Further north towards Ravine des Casoars are several large dolines formed in the dune limestone, but these are as yet unexplored.

Five major folds in the Cambrian Kan-mantoo bedrock have been mapped along this coastline plunging to the southwest. The folds are regional structures that extend across the island to the Kangaroo Island Shear Zone. From Vennachar Point to Cape Borda, the coastline follows a northeasterly to northerly trend and is dominated by steep coastal cliffs up to 100 m high. Five rivers traverse the plateau in a broadly south-westerly direction along the coast between Cape du Couedic and Vennachar Point, with their general courses controlled by these regional-scale fold structures.



Figure 14. Vennachar Point: shaft 35 m deep connects to a geo, through a cleft with a rounded boulder beach.

Bore Beach trace fossils

This site is located on private property on the southern shore of the Dudley Peninsula. It has been studied in detail by Camens and others (2017). A series of trace fossils or animal tracks occur within cross-bedded dune limestone (calcarenite) of the Bridgewater Formation (Figure 15). The tracks are exposed in gently dipping laminae of the calcarenite within the tidal zone, and are periodically covered by sand. There are several trackways as well as individual footprints of reptiles, shorebirds, extant species such as possums, kangaroos and the Tasmanian Devil (Figure 16). Of particular interest are the tracks of large extinct marsupials such as diprotodons, short-faced (sthenurine) kangaroos and thylacines. Possible contenders for the diprotodontid tracks include the giant wombat Phascolonus gigas, the "marsupial tapir" Palorchestes azael and a juvenile diprotodontid (*Diprotodon optatum* or *Zygomaturus trilobus*).



Figure 15. Boar Beach site BSB; trace fossils cover the gently sloping bedding plane at the base of the cliffs.

The deposits have been dated using Optically Stimulated Luminescence (OSL), which dates the last time the sediment was exposed to sunlight. Samples taken above and below the trace fossil layer are indistinguishable at their one standard deviation uncertainty ranges, and suggest that the fossilized dune sequence accumulated relatively rapidly. The consistency of the dating results



Figure 16. (a) Tracks of an extinct juvenile Diprotodontid.



Figure 16. (b) Tracks of a large short-faced (Sthenurine) kangaroo.

provides a mean age of 135 ka for the trace fossils at Boar Beach. This puts them in the middle of the Last Interglacial when sea level was higher, and the climate warmer and wetter. A concentration and overprinting of tracks at one point suggest animals were congregating to drink at a shallow freshwater lagoon at the back of the beach.

Flour Cask Bay

This site is located on the exposed south coast of the island, at the eastern end of D'Estrees Bay. The name derives from cask markers mounted on poles to guide sailors into a whaling station established there in the early 19th century. There are sea cliffs 40-50 m high, formed in mid-Pleistocene dune limestone overlying Pliocene to early-Pleistocene Cape Hart limestone. At the base of the cliffs are well developed shore platforms and small sea stacks (Figure 17), with solutional potholes and tafoni in the dense limestone. Several pedogenic calcrete layers are visible in the cliffs, with flank margin caves and outside stalactites up to 35 m above present sea level. About 1 km west of the access



Figure 17. (a) Shore platform formed in Cape Hart limestone. (b) Sea stacks in early Pleistocene limestone.



Figure 18. (a) Dune limestone cliffs along Flour Cask Bay. (b) Fulgurites at eroded cliff-top dune.

track, fulgurites are well exposed on a cliff-top dune (Figure 18). These are formed in sand when lightning hits the ground, fusing and vitrifying the grains into hollow tubes about 20-40 cm long, with some minor branching.

Point Ellen, Vivonne Bay

At Point Ellen, on the western side of Vivonne Bay, there is a sequence of limestones and metasandstones exposed in the low cliff of the point (Figure 19). The wide shore platform is formed in Cambrian metamorphosed sandstones and migmatites from melting, with extensive folded and fractured quartz and feldspar veins. There are small platy fragments of brown muscovite mica and dark green to black tourmaline crystals associated with the veins. Above this is the Point Ellen limestone (Pliocene, about 2 million years old), which contains abundant bivalve shell fragments of Anodonta species as well as rounded boulders of the sandstone (Belperio 1995). This suggests that the Point Ellen limestone was formed in shallow water and subject to wave action eroding the sandstone. This limestone is capped by a thin and partly eroded red soil or terra rossa, suggesting a long period of stability above the reach of waves. A thick dune



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Figure 19. (a) View towards shore platform and cave from Point Ellen. (b) Contact between Point Ellen limestone (below) and Bridgewater Formation dune limestone (above). (c) Contact between Cambrian metamorphic rocks (below) and Pliocene shelly limestone (above). (d) Breached flank margin cave with solution tubes.

limestone of Pleistocene age (less than 2 million years old) covers the red soil and extends seawards to cover the metamorphic rocks in places, with the sea having eroded the Pliocene limestone to form a low cliff.

The point contains a shallow cave, which today is within reach of storm waves. It appears to be a breached flank margin cave with several deeper cavities at the same level along a ledge (Mylroie & Mylroie 2009). This implies that it formed at the junction of fresh water and sea water when sea level was higher. The most likely age is about 125 ka when sea level was 3-5 m higher and the climate was much warmer and wetter than today. Marine benches of this age and elevation are widespread on the south coast of Kangaroo Island.

Conclusions

The Kelly Hill karst is a syngenetic karst with some marginal mixing corrosion, and collapse domes in many caves. The underlying Cambrian metasandstone acts as an aquiclude, with water flows down gradient to the coast also fed by active water sinks on the margins of the Grassdale Lagoon. Pleistocene uplift has driven landscape incision and development of caves at several levels in the dune limestone from 10-12 m, 20-25 m and 30-35 m asl. There are multiple caves at +3 m to +4.5 m asl, probably of Last Interglacial age, and – from this – it would seem no uplift has occurred since then. Coastal springs and submarine upwellings are active after heavy rain.

In the Kelly Hill caves, the passage cross sections are remarkably consistent, with tensional collapse domes linked by short rift passages. The domes are all between 15 and 20 m across and the rift-like

sidewalls are generally choked with collapse debris. Subsequent to the collapse, there has been extensive speleothem decoration and the varied orientations of stalagmites would suggest that the sinking or rafting down of limestone blocks on the floor is ongoing. In many places, the collapse domes have breached to the surface to provide sinkholes, while in other places solution pipes provide access to the domes.

The extensive dune limestones on Kangaroo Island form sea cliffs up to 60 m high and their upper surfaces are punctuated by dolines. These fall into several types: small collapse dolines leading to shallow caves, solution dolines with pipes, broad solution dolines partially filled with sand and flank margin caves breached by coastal cliff retreat. Mapping of these features is continuing and many more features are visible on LIDAR data, which has proven to be an invaluable tool for documentation of the karsts.

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