7th Australia and New Zealand Geomorphology Group Conference

Chillagoe Field Trip Excursion Guide

5th October, 1996

prepared by

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Chillagoe Field Trip
October 5-6th, 1996

Saturday 5th October

Morning

Depart 7.45 am Hydes Hotel in Lake Street
Arrive at Chillagoe 11-11.30
Book into accommodation at:
Chillagoe Bush Camp (8 people) or Chillagoe Caves Lodge (34 people)
Packed lunch available from the Black Cockatoo Hotel ($5.50), or you can take your own lunch.

Afternoon

Travel to Mangana (15 km NW Chillagoe), eat packed lunch at the Archways, then spend the afternoon at Red Cap Track. Return to Chillagoe by 5-5.30 pm.

Evening

Buffet dinner served at Chillagoe Caves Lodge ($10.00 per person)
Optional caving opportunity with Derek Fabel.
Evening entertainment at the Black Cockatoo Hotel.

Sunday 6th October

Morning

Hot breakfast at 7 am at Chillagoe Caves Lodge ($7.00 per person)
Check out of rooms and be ready to depart by 8.00 am.
Travel to field site. Morning tea and lunch packed (13.00 per person) for in the field.

Afternoon

In the field until mid-afternoon,
Stop at Almaden Hotel for afternoon tea and/or Beer.
Plan to be back in Cairns by 6.00 pm.

WHAT TO BRING

Long-sleeved shirt (temperature may be slightly cooler in the evening)
Water bottle (1 L minimum capacity) Dehydration is a potential problem
Sturdy shoes, hat and sunscreen

Accommodation:

Linen is supplied, and accommodation paid for.

Food

$5.50 Saturday (packed) lunch by the Black Cockatoo Hotel.
$30.00 Package deal with Chillagoe Caves lodge: includes Saturday night dinner, Sunday Breakfast, packed morning tea and lunch for Sunday while in the field.
There are limited places to by food in these areas, so it is advised to take advantage of this fuss-free offer.

**** Please advise the group leader if you suffer from any medical condition, so that in case of an emergency, proper treatment can be carried out ****

Introduction

Chillagoe is a small town (population ~300) lying approximately 130 km west of Cairns (Fig. 1), some two and a half to three hours by road through Mareeba and Dimbulah. It is located to the west of the Divide, at an altitude of ~350 m asl; the main perennial rivers draining the area are the Mitchell and Walsh Rivers, both of which flow to the Gulf of Carpentaria.

Chillagoe is well known both for its early mining history and its spectacular karst landscape, with steep-sided limestone towers rising up to 65 m above soil-covered pediments, and it has become a popular tourist destination.

Climate

The region has a tropical monsoonal climate, with a total rainfall of ~830 mm. Most of this falls in the short wet season (December-March), when maximum temperatures in excess of 38°C are common. In the long dry season rainfall averages <20 mm each month (except November), when the area is in the rainshadow of the prevailing easterly winds. Even in winter, the maximum daily temperature frequently exceeds 25°C.

Vegetation

Most of the region is covered by open eucalypt woodland with trees up to 15 m high. The ground cover consists mostly of grasses, including spear grass, wire grass, kangaroo grass and sorghum. Large paperbarks, eucalypts and scattered figs are found along major watercourses. The introduced rubber vine has overgrown the native plants in some areas, and around the sites of early settlements are dense stands of the exotic Chinese apple.

The limestones support a distinctive vegetation of semi-evergreen and deciduous vine thickets with softwood emergents, particularly figs and kurrajongs. Stinging trees are found in many cave entrances.

Fauna

Grey kangaroos and wallaroos inhabit the open woodland, while agile and rock wallabies are found on the limestone outcrops. Fourteen species of bats have been recorded in the area, including three species of flying fox and nine bat species that live in the caves. The caves are also home to the grey swiftlet.

History

Aboriginal occupation of the Chillagoe district dates back at least 19,500 years. Small areas of rock art are located under overhangs around the bases of some limestone towers.

The first European to pass through the area, in 1848, was the ill-fated Edmund Kennedy. In 1872 Hann discovered gold in the Palmer River to the north; this lead to a gold rush in that area. Pioneer cattlemen took up selections to supply beef to the mining camps, and in 1887 William Atherton settled at Chillagoe; the name Chillagoe reputedly came from an old sea shanty.

Copper deposits were soon discovered in the area, and the local mining entrepreneur John Moffat formed a company to build a railway from Mareeba to Chillagoe in order to exploit them. The railway was completed in 1900, and construction of smelters in Chillagoe, to process the ore being mined, commenced. The smelters opened in 1901 but had a troubled, unprofitable history, closing and re-opening several times, until they closed for the last time in 1943. Ore reserves in the area were often over-estimated, and the cost of building and operating the railway and smelters was far in excess of the profits from the mining operations.

At its peak in 1917 some 10,000 people lived in Chillagoe, which had 12 hotels, 2 soft drink factories and 3 newspapers.

The Chillagoe mines were the cause of a major corruption scandal. E.G. (Red Ted) Theodore was Queensland State Treasurer in 1918 when the Chillagoe railway and smelters were bought by the Queensland government, along with some leases at Mungana, 15 km NW of Chillagoe, to revive mining in the area. However, the operations were unprofitable, and by 1920 the government had to buy more mines to keep the smelters going. A change of government led to an investigation of the transactions by the Auditor-General, and this culminated in the Mungana Royal Commission of 1930, which concluded that Theodore was guilty of fraud and dishonesty. By this time Theodore was Federal Treasurer, and he was forced to resign. In a subsequent civil case brought by the government in 1931 against Theodore, the jury found him not guilty of fraud and conspiracy, but his political career was ruined.

Mining

The Chillagoe district has a substantial reputation as a mineral field but its overall production has been small; up to World War 1, only 24,000 tonnes of copper and 32,000 tonnes of lead had been produced. The largest mines, Girofla and Lady Jane near Mungana, were apparently pipe-like bodies worked to a maximum depth of 840 feet. Most other deposits were smaller and shallower.

Exploration in the area through the 1960's and 1970's culminated in the opening in 1986 of Red Dome gold mine, 13 km WNW of Chillagoe. At this site a Late Carboniferous rhyolitic intrusive has metamorphosed the Siluro-Devonian limestones and interbedded sediments to form marble and skarn. The gold occurs as tiny disseminated grains with silicates in the skarn and associated with copper sulphides in the intrusive. The upper part of the Red Dome deposit includes a breccia which may have formed by collapse into a karst cavity, the origin of which is unclear. The mine is an open-cut, about 300 m deep. Mining has now ceased, but production of gold and copper sulphide concentrate is continuing from stockpiled ore; approximately 100,000 ounces of gold is produced each year. The mine is expected to close completely in 1997. Several other nearby deposits have been proved by drilling, but there are no plans to commence mining in the near future.

Limestone near Chillagoe is quarried for lime production, and quarrying of large blocks of marble for monumental use has occurred intermittently.

Cattle industry

Cattle grazing has been carried on in the area since it was first settled. However, production is only moderate, because the extremes of climate, particularly the long dry season, mean that only the hardier breeds, such as Brahmans and their crosses, can thrive. Until recently Mungana was the railhead of the Burke Developmental Road, which extends westwards to the cattle stations in the Gulf country. The railway to Chillagoe is now closed, and cattle are trucked directly to the abattoirs.

Geology

The Chillagoe area is split into two geologically distinct regions by the major Palmerville Fault, which runs NW-SE near Chillagoe, and extends hundreds of kilometers further north (Fig. 2).

To the west of the Palmerville Fault are the Precambrian metamorphics of the Dargalong Province, consisting largely of biotite gneiss with large crystals of white feldspar and pink garnet. The gneisses have been intruded by the Early Silurian Nundah Granodiorite (Fig.7).

To the east of the fault is the Hodgkinson Province (Fig. 2), a large sedimentary basin that covered over 75,000 km^2 and extended beyond the present coastline. It accumulated sediments from the Ordovician until the Late Devonian or possibly Early Carboniferous. The Hodgkinson Province represents the northernmost part of the Tasman Orogenic Zone.

The Ordovician sequence occurs as a thin fault sliver east of the Palmerville Fault (Fig. 6); it is dominated by quartz sandstones and siltstones, with rare thin interbedded limestones in the Mitchell-Palmer area to the north.

The Early Silurian - Early Devonian Chillagoe Formation outcrops for 300 km along the western edge of the Hodgkinson Province (Fig. 2) as a belt often several kilometers wide. It consists of limestones interbedded with chert, basalt and sandstone (Fig. 3). The relative proportions of the different lithologies vary; around Chillagoe limestones predominate. Total stratigraphic thickness of the formation in this area is about 1 km, but fault repetitions have increased the outcrop thickness to around 4 km. The limestones accumulated in shallow marine conditions (Fig. 4), probably on a gently sloping ramp, and subtidal facies are most common. Fossils are abundant, particularly corals, stromatoporoids, crinoids, brachiopods and large bivalves. There were apparently no reefs at the time, although carbonate sand shoals and mud mounds were scattered across the ramp. Shallow water limestone deposition persisted in the region almost continuously for about 40 million years (Fig. 3), indicating a remarkably stable environment.

Some previous studies have interpreted the Chillagoe Formation as a shallow water shelf that collapsed down the continental slope. The limestone towers were postulated to be blocks of shallow water limestone that had fallen downslope into deeper water; the limestones around the towers were therefore interpreted as hemipelagic and turbiditic facies. However, detailed mapping has shown that beds of shallow water limestone can be traced continuously for over 4 km, through both the towers and the intervening pediment outcrops, so the towers are not isolated blocks within the stratigraphy.

Succeeding the Chillagoe Formation is the siliciclastic Hodgkinson Formation, which outcrops over most of the Hodgkinson Province (Fig. 2). It comprises a substantial thickness of quartzofeldspathic turbidites, deposited in deep water with local carbonate build-ups, from the Early to Late Devonian.

The youngest unit of the province is a very coarse, poorly sorted conglomerate of Late Devonian or Early Carboniferous age, deposited during the initial stages of a major tectonic event. Compression during this deformation resulted in thrusting along and adjacent to the Palmerville Fault (Fig. 5); whether the thrusting was directed towards the west or east is a subject of contention. The thrust faults run subparallel to bedding and are closely spaced in the Chillagoe Formation around Chillagoe (Fig. 6), causing extensive repetition of the sequence. Deformation was so intense that bedding is always very steep or overturned. Brecciation of the limestone is widespread, and probably resulted from the faulting. The cavities between the angular fragments of the breccia are sometimes filled with subhorizontal laminated fault gouge.

In the Late Carboniferous and Early Permian (~360-275 Ma) thick rhyolitic ignimbrites were erupted across the area during a long period of explosive volcanic activity, forming several overlapping calderas (Fig. 5). Fluviatile and lacustrine sediments interbedded with the volcanics sometimes contain plant remains. The waning stages of magmatism were characterized by the emplacement of small high level microgranite plutons.

Erosion of the deformed Hodgkinson Province strata and Permo-Carboniferous volcanics occurred through the Late Permian and Triassic. In the Early Mesozoic, broad downwarping of northwestern Queensland formed the Carpentaria Basin, and allowed a shallow sea to enter this region. Deposition in the Carpentaria Basin did not affect the Chillagoe area until the Late Jurassic and Early Cretaceous, when fluviatile and shallow marine sandstones and mudstones of the Gilbert River and Wallumbilla Formations were laid down (Fig. 5). These sediments extended across the western edge of the Hodgkinson Province.

In the mid-Creteceous the sea retreated, and the area has undergone continuing erosion through the Late Cretaceous and Tertiary (Fig. 5). There are no significant Tertiary sediments in the Chillagoe region; thin sequences of this age are present in the Karumba Basin to the west.

The Mesozoic sediments that lie across the Palmerville Fault have been deformed by relatively small scale movement along the fault some time during the Late Cretaceous and/or Cainozoic; several periods of movement may have occurred. An earthquake was recorded on the Palmerville Fault or a closely adjacent fault at Mungana about 2 years ago; no surface rupture was evident.

Regional physiography

Four main physiographic units have been defined in the Chillagoe region, and each is clearly related to the underlying geology.

The Mungana-Chillagoe Uplands have developed on the Chillagoe and Hodgkinson Formations. The limestones form prominent towers, and are separated by lower, rounded ridges of chert (Fig. 6). The ridges and towers run more or less parallel to the regional strike, which is NW-SE near Chillagoe. The limestone country grades to the east into hilly terrain underlain by the Hodgkinson Formation and Permo-Carboniferous granites and rhyolites (Fig. 7). Near Chillagoe some of the granites have weathered to form "metal hills", piles of rounded bare boulders that rise up to 100 m above the plain. The boulders ring like a bell when struck with a hammer.

To the southwest the Mungana-Chillagoe Uplands change into the Tate-Lynd Uplands, which have a more subdued topography developed mainly on the Precambrian Dargalong Metamorphics (Fig. 7).

The Featherbed Range, which rises up to 315 m above the surrounding country, is a rugged dissected tableland underlain almost entirely by rhyolitic ignimbrites.

The Red Plateau comprises Mesozoic sediments of the Carpentaria Basin, and slopes gently westwards on a regional scale. It is not well developed in the Chillagoe area, but to the NW it forms a prominent plateau with a cliffed eastern boundary.

Karst geomorphology

The limestones of the Chillagoe Formation have weathered into a spectacular karst landscape, dominated by limestone towers (Fig. 8). It is notable that the soluble limestone forms topographic highs elevated above the hills developed on the associated chert, sandstone and basalt. Individual limestone towers (or bluffs) rise up to 65 m above the plain around Chillagoe, and can be 1 km long. Towers in the Mitchell-Palmer area to the north may be larger: over 100 m high, 4 km long and 1 km wide. In plan they are generally lens-shaped, with the long axes parallel to the regional strike (Fig. 8). Detailed mapping around Mungana has shown that the towers are separated by faults, either major thrust faults parallel to bedding (Fig. 6) or smaller scale cross-faults trending roughly NE-SW. The faults probably represent lines of weakness along which preferential weathering has occurred, leaving the towers isolated from each other.

Surrounding the towers, and developed in the same limestone, are low angle pediments (Fig. 9). Some are narrow zones about 20 m wide, with relatively steep slopes (~20°) covered in loose rock. These might be better termed ramps, and may represent Richter slopes. The more extensive pediments have slopes of only a few degrees, and may extend for hundreds of meters. Low bevelled limestone outcrops, showing rounded solutional forms, protrude through the soil on these pediments. Pediment development appears to be greatest closest to the main drainage lines.

The pediments appear to be eroding into the towers, sharpening their sides and sometimes cutting large towers into smaller elements. The process of pediment extension is uncertain. It has been postulated that limestone solution at plains level is evident at some localities, where the tower edges are apparently undercut, but although water marks are present on the tower sides, there is no notching at this level. However, solution may be occurring along subhorizontal joints; one small tower that has toppled over shows well-developed half-tubes along the horizontal joint plane that forms its base.

Most of the towers have very well developed surface karren features, particularly pinnacles. Rillenkarren (flutes) 1-2 cm across drain down the tower faces, merging into rinnenkarren (runnels) up to 30 cm deep and 30 m long. Within the rillenkarren are often low subhorizontal ribs of limestone (solution ripples). Flat solution pans (kamenitsa), up to 30 cm across and 10 cm deep, are very common, and always have an outlet on one side. Solution bevels, smooth planar features cutting across other structures at a low angle from the horizontal, are frequently present. They usually grade sharply upwards into steep fluted surfaces. Microrills, miniature flutes about 1 mm across, appear to result from limestone dissolution by wallaby urine, and are confined to small patches where wallabies sit. Wallabies are also probably responsible for very smooth, polished areas under overhangs; the glassy polish may result from physical wear by their footpads.

Solution along vertical joints and bedding planes within the limestone has produced grikes (vertical slots); these range in size from centimeters across to extensive corridors that may be 10 m wide and 30 m deep. A few of the larger towers contain amphithéatre-like depressions filled with large limestone blocks; these probably represent large collapsed cave passages. However, some closed depressions within towers lack evidence of collapse, and may be solution dolines.

Beneath the soil cover the limestone shows smooth, rounded forms, clearly visible on the pediment areas where the soil has been stripped away. There is often a sharp subhorizontal line of demarcation between the karren features formed above and below the soil.

Some towers have developed in coarse sugary marble, formed by metamorphism around the margins of the granites. The marble towers have a rounded, domed appearance; rillenkarren are shallower and rounder than on limestone towers, and may be absent altogether. Exfoliated sheets are common on the bare marble surfaces. Because there are few joints and little evidence of bedding, grikes are absent. The subsoil weathering of the marble produces a micropitted surface, particularly evident in fine-grained varieties; this contrasts with the smoother subsoil surfaces formed on unmetamorphosed limestone.

Limestone exposures along watercourses frequently display asymmetrical solution scallops. These are best developed along the larger rivers like the Walsh River, but examples are also present between some towers.

Caves

The limestone towers are densely cavernous, and hundreds of caves are known in the Chillagoe area. In general the highest, largest towers have the most extensive cave systems; the longest cave has over 6 km of passage. The caves are mostly joint-controlled mazes (Fig. 10). Typically, cave entrances are in the sides of towers, and are entered directly from the pediment or from corridors through the towers; there may be multiple entrances for each cave. No cave entrances are known on the pediments, and few caves extend beneath the pediments from the towers. Most passages are rifts, i.e. they are more or less straight, much taller than they are wide, and narrow upwards as the walls slope towards each other. Large chambers have often formed at passage intersections, and can be 50 m or more across and up to 30 m high. Passages frequently connect upwards with grikes, so daylight chambers are common (Fig. 10), particularly where there has been roof collapse. Where the walls are not covered with secondary calcite deposits, they are smoothly rounded, and display typical phreatic solution features like half-tubes, pendants, large irregular scallops and spongework. A few passages, moderate sized solution tubes linking larger passages or chambers, have occasional asymmetric scallops.

The floors of the caves mostly lie approximately at the level of the pediment outside the cave, and are more or less flat and covered with silt and/or rubble. Originally the passages probably narrowed downwards in the same way that they narrow upwards; the lower half or third is therefore filled with sediment. In a few caves bedrock-floored passages are known; in Christmas Pot the cave terminates downwards in a narrow rift that carries permanent water, at a level some 15 m below the surrounding pediment.

The caves are nothephreatic in origin, i.e. they formed below the water table by the slow movement of groundwater along preferential pathways, mostly vertical joints or bedding planes. At this time the water table was above the level of the present tower summits.The general lack of directional wall scalloping indicates that the groundwater within the caves was slow-moving. It cannot have been completely stationary as otherwise it would have become saturated with respect to calcite; in this case no further solution could take place and large caves could not form.

The caves were probably drained quite quickly and continuously. There is no evidence of superimposed horizontal development, as might be expected if there had been any sustained period of stillstand during the cave-draining episode.

Subsequently the passages have been partially filled with sediment, a combination of collapse blocks and finer grained material washed in from outside the towers. Unsurprisingly, the level of sediment in the caves approximately matches the local base level, i.e. the pediment level outside the caves. There is little evidence of later passage modification, apart from minor karren development due to the effects of water trickling down the walls from the tower surface above. The sediment on the cave floors is sometimes locally incised by small stream channels, and partial removal of previously thicker sediment infill is shown by the presence of false floors in some caves. These are calcite crusts that once covered the cave floor, and have been left attached to the cave wall when the sediment beneath was washed away.

Bone breccia deposits have been discovered within the sediment in some caves, and have yielded bones of giant wombats and ziphodont crocodiles. The fauna is probably Pleistocene in age. Cemented bone breccias are also found on the surface of a few towers, along with eroded speleothem remnants, indicating the former presence of caves now almost completely removed by erosion.

Secondary calcite deposits (speleothems) are abundant in almost all caves. The most abundant form is cave coral, rough knobbly protrusions usually only a few centimeters long that cover large areas of cave walls, along with moonmilk, a soft white powdery encrustation. Stalactites and flowstone are common; the stalactites are up to 1 m across and 10 m long, and many terminate not in a point but as a flat subhorizontal plane covered in small cave coral. Such stalactites are called "suckerpads" or "elephants' feet". Their origin is uncertain; the planar terminations do not appear to represent an old floor or water level, as they occur at a variety of heights, even within the one passage, and some are slightly inclined.

The speleothems generally have a chalky, porous appearance. This reflects their presence in caves which, because of the multiple entrances and daylight holes, are well-ventilated. In these low humidity conditions evaporation as well as CO_2 loss plays a part in the calcite precipitation, and gives the characteristic chalky "dead" appearance to speleothems that may be actively growing.

Only those few caves with continuous high humidity environments, due to their small size and/or limited number of entrances, contain translucent and coloured speleothems. Helictites are also often present in these caves, and oolites and calcite dams may occur on the floors.

On the walls of many cave entrances and daylight chambers phytokarst is well developed. Algae (and/or cyanobacteria) have etched the walls, leaving sharp prominences, the size of pencils or narrow sticks, that all point in the same direction towards the light.

Hydrology

Limestone springs are common throughout the area, e.g. Chillagoe Creek is perennial, as it is fed by several springs that flow year-round. Some springs have dried up in recent years, probably as a result of water-table lowering around the Red Dome open cut. The conduits feeding the springs may be a meter or more in diameter, based on drilling records from around Chillagoe; water-filled cavities have been encountered during drilling at depths of up to 90 m. During excavation of the open-cut, cavities lined with large calcite crystals were found within the marble at depths of over 200 m, but these appear to be related to the mineralization and are not similar to the caves within the towers, being smaller and more irregular in shape.

Many of the streams and springs have extensive deposits of porous calcite tufa as encrustations on the stream beds and banks, and sometimes as substantial tufa barriers forming cascades. Precipitation of the calcite is driven by CO_2 degassing but aided by evaporation.

There are also extensive relict deposits of travertine, which typically lie well above present stream levels as benches and terrace remnants. The travertine is horizontally bedded and quite dense, and dating indicates that it may have been deposited during interglacial periods at 260 ka and 80 ka (Dunkerley 1989).

In the dry season the water table lies 10-15 m below the level of the plains; standing water occurs at this height in a small number of caves. In the wet season some caves may flood. Water flows in directly from the tower surfaces above, down grikes and daylight holes, and is temporarily dammed within the caves. Surface pools may also form around the bases of some towers. Water marks on cave and tower walls indicate the flood levels; the lack of notching associated with these levels indicates that the flooding is not responsible for substantial cave or tower modification. The water drains in a few weeks; sites closest to a creek drain quickest.

Landscape evolution

The limestones of the Chillagoe Formation were deformed into subvertical thrust sheets by the Early-Middle Carboniferous tectonic event that affected the entire Hodgkinson Province (Fig. 5). In the Late Carboniferous and

Early Permian, ignimbritic volcanics were erupted over the area, which was dry land at the time, because the volcanics are interbedded with fluvial and lacustrine sediments. Thus the limestones had already been exposed to weathering by the Late Carboniferous.

Following the ignimbritic activity there has been sufficient erosion to unroof the high level granites that intruded the volcanics soon after they were erupted. These granites presumably came within 2 km of the surface (the maximum thickness of the volcanics). Therefore the amount of erosion since the Carboniferous may have been of the order of 2 km or less. As the granites are directly overlain by Late Jurassic and Early Cretaceous sediments of the Gilbert River Formation, the erosion must have occurred prior to this (Fig. 5).

The basal Late Jurassic unit of the Gilbert River Formation comprises fluviatile ferruginous quartzose sandstones. Small outcrops of this lithology occur around the bases of several limestone towers, at elevations of 340-380 m asl (Fig. 11), and also outcrop on the summits of two towers, at heights of over 400 m asl. Thus the towers clearly had at least 60 m of relief in the Late Jurassic. The tower summits may have been lowered as a result of post-Late Jurassic erosion, although the presence of Gilbert River Formation close to the highest points of two suggests that the amount of lowering may have been small.

Thus the tower karst at Chillagoe was well developed by the Late Jurassic, and has probably been forming since the Carboniferous.

It is uncertain when the caves formed. They could have developed very early, in the Carboniferous and Permian, and then been drained by the same episode of downcutting and erosion that formed the towers. Alternatively, they might owe their origin to the burial of the towers by the Late Jurassic sands of the Gilbert River Formation.

The fact that large caves are unknown beneath the pediments around the towers may argue for the latter scenario, that cave formation post-dates tower development. In addition, no outcrops or unlithified equivalents of the Gilbert River Formation sands have been found within the caves, suggesting that the cave entrances were not open when the sands buried the bluffs.

If the caves formed in the Late Jurassic and Early Cretaceous, they would have been drained as the sandstones around the bluffs were stripped away. This probably occurred largely in the Late Cretaceous, when a major uplift and erosion event affected the entire eastern Australian margin.

In any case, it is clear that the caves are of considerable antiquity, and must be pre-Tertiary in origin.

References

Bernecker, T., 1993. A sedimentation model for the Chillagoe Formation in the Mungana area, north Queensland. *Unpublished PhD thesis, Department of Geology, La Trobe University*, 1-133.

Best, J.G., 1962. Atherton 1:250,000 Geological Series. *Bureau of Mineral Resources Explanatory Notes E55/5.*

Bultitude, R.J., Dash, P. and Domagala, J., 1990. Excursion D - Hodgkinson Basin, north Queensland. *Pacific Rim 90 Field Trip Guide*, 1-30.

Bultitude, R.J., Green, P.M. and Domagala, J., 1987. Review of the stratigraphy of the southwest Hodgkinson Province. *Queensland Government Mining Journal* 88, 187-191.

Bultitude, R.J., Rees, I.D. and Garrad, P.D., 1995. Bellevue Region Sheet 7764. *Geological Survey of Queensland, 1:100,000 geological map commentary*, 1-76.

Chillagoe Caving Club, 1982. Chillagoe karst, 187pp. Chillagoe Caving Club, Cairns.

De Keyser, F. and Wolff, K.W., 1964. The geology and mineral resources of the Chillagoe area, Queensland. *Bureau of Mineral Resources Bulletin* 70, 1-130.

Dunkerley, D.L., 1987. Deposition of tufa on Ryans and Stockyard Creeks, Chillagoe Karst, north Queensland. *Helictite* 25, 30-35.

Dunkerley, D.L., 1989. Mechanisms and chronology of travertine deposition in the Chillagoe Karst, Queensland. *Abstracts 4th ANZGG Conference, Buchan*, 32-33

Ford, T.D., 1978. Chillagoe - a tower karst in decay. *Transactions of the British Cave Research Association* 5, 61-84.

Hall, L.S. and Richards, G.C., 1985. The bats of Chillagoe. *Tower Karst* 5, 13-22.

Jennings, J.N., 1982. Karst of northeastern Queensland reconsidered. *Tower Karst* 4, 13-52.

Marker, M.E., 1976. A geomorphological assessment of the Chillagoe karst belt, Queensland. *Helictite* 14, 31-49.

Pearson, L., 1982. Chillagoe karst solution and weathering. *Tower Karst* 4, 58-70.

Pearson, L.M., 1987. Chillagoe souvenir guide, 40 pp. L.M. Perason, Cairns.

Robinson, T., 1980. An introduction to the palaeontology of the Chillagoe area. *Tower Karst* 3, 5-8.

Smart, J., Grimes, K.G., Doutch, H.F. and Pinchin, J., 1980. The Mesozoic Carpentaria Basin and the Cainozoic Karumba Basin, north Queensland. *Bureau of Mineral Resources Bulletin* 202, 1-64.

Webb, J.A., 1989. The age and development of the Chillagoe karst, north Queensland. *Abstracts 4th ANZGG Conference, Buchan*, 34-35.

Willmott, W.F. and Tresize, D.L., 1989. Rocks and landscapes of the Chillagoe district, 32 pp. Queensland Department of Mines, Brisbane.

Wilson, P.A., 1975. Observations on the geomorphology of the Chillagoe limestones. *Proceedings 10th ASF Conference, Brisbane*, 69-73.

Excursion sites

Site 1 - Mungana area (Figs 6, 7)

(a) Piano Tower

This tower is largely composed of beds of crinoidal limestone that dip subvertically. The views from the top are excellent - to the west on the skyline, the dissected tableland of the Featherbed Ranges; to the northeast in the middle distance, the hills of the Redcap Volcanics and Ruddygore Granodiorite, and closer to Piano Tower, several limestone towers separated by low, continuous, rounded chert ridges. The largest limestone tower to the north-northeast is Queenslander (site 4). To the west and southwest are continuous ridges of sandstones (Hodgkinson and Mulgrave Formations, northeast to southwest respectively); on the far side of the furthest of these ridges is the Palmerville Fault; beyond that lie the high grade Dargalong Metamorphics (Tate-Lynd Uplands).

To the south is the Red Dome open cut; further south and west the tailings dam and storage dam for the mine can be seen.

Almost on top of the tower, at an elevation af around 420 m, is a small outcrop of Gilbert River Sandstone.

(b) Old hut

To the east of the hut a bed of fossil corals outcrops; individual heads of the colonial tabulate corals *Favosites* (honeycomb coral),*Heliolites* (sun coral) and *Halysites* (chain coral) are common. This bed is Lower Silurian in age, and occurs towards the base of the Chillagoe Formation (Fig. 3).

Further east is a rounded chert ridge. Abundant chert float covers the slopes; this chert consists largely of sponge spicules and is laminated.

(c) Cave CH208

This small cave shows the typical passage shape of Chillagoe caves: high, narrowing upwards, with a silt and rubble-filled floor. Just outside the entrance is a small outcrop of Gilbert River Sandstone, apparently overlying the limestone pediment, and lying approximately at the level of the cave roof. There is no evidence of Gilbert River Sandstone within the cave, suggesting that the cave was not present or at least not open when the sandstone was deposited.

Site 2 - The Archways (Fig. 8)

The Archways is a cave system with several daylight chambers, and displays many of the features typical of Chillagoe caves: phreatic characteristics (pendants, irregular scallops, spongework, half tubes), passage shape and orientation, speleothems (cave coral, stalactites, sucker-pads), phytokarst.

To the northeast and northwest of the car park are two fossil localities, where beds of abundant, well-preserved brachiopods and bivalves can be seen.

Site 3 - Ryan Imperial Tower (Fig. 8)

On the western side of the tower is a small aboriginal art site. Note the watermarks on the tower walls, formed during the wet season when a pool of water develops here. Note also the lack of notching at these marks.

To the northwest, on the northern side of the road, is a small fallen tower. The base is a subhorizontal joint plane with common half-tubes. The tower toppled prior to 1975, yet there is no vertical karren development; all the visible rillenkarren clearly formed before the tower fell. On one side of the tower are some hammer marks, dating to mid-1986; they appear almost completely unmodified by subsequent weathering, lacking both karren and lichen/algae.

Site 4 - Queenslander Tower (Fig. 8)

(a) West side of tower

This area shows excellent karren development (rillenkarren, rinnenkarren, solution ripples, solution bevels, kamenitsa, microrills, cave entrances). Around the base of the tower, particularly on the northern side, is a soil-covered pediment with low rounded limestone outcrops.

(b) Breccia bluff

The cave in the base of this bluff shows typical cave features, and also has excellent examples of "wallaby-foot polish". The bluff itself is composed of very coarse, poorly sorted fault breccia, which in places has a reddish matrix with subhorizontal laminations (apparently fault gouge).

(c) Bivalves

Several limestone slabs in the grass display large megelodont bivalves, with very thick hinge areas. The shells are mostly articulated and appear to be more or less in growth position.

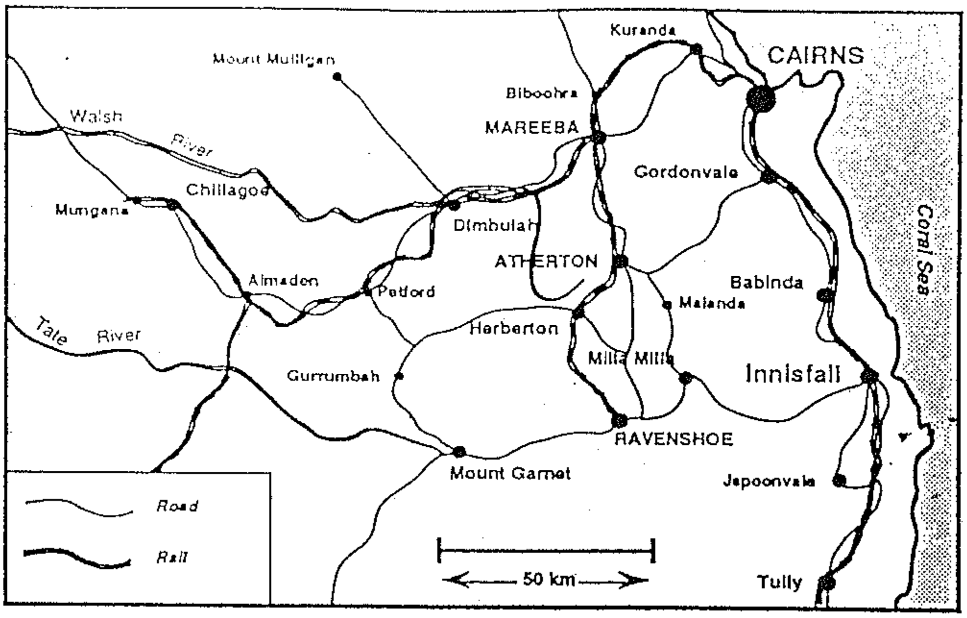


Fig. 1. Location of the Chillagoe - Mungana area (from Bernecker 1993).

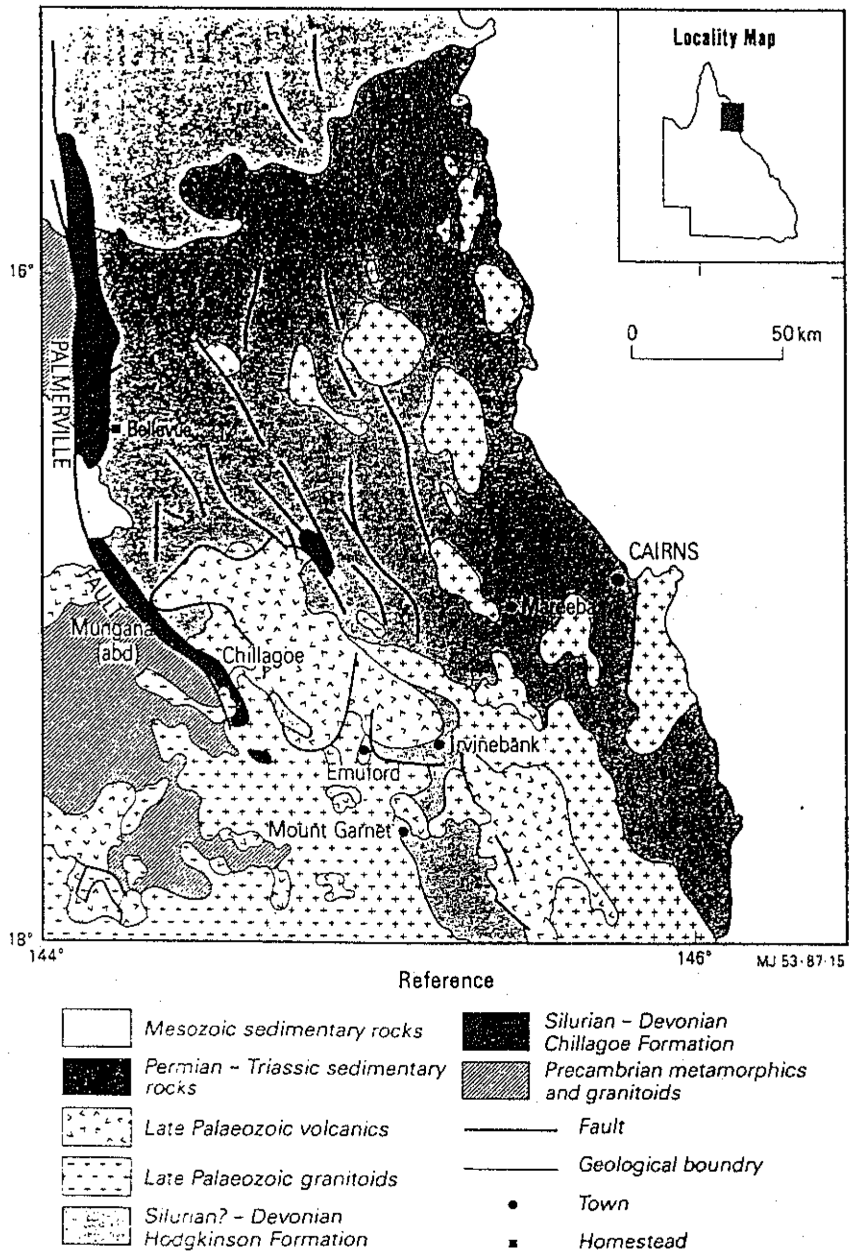


Fig. 2. Regional geology of the Hodgkinson Province (from Bultitude et al. 1987).

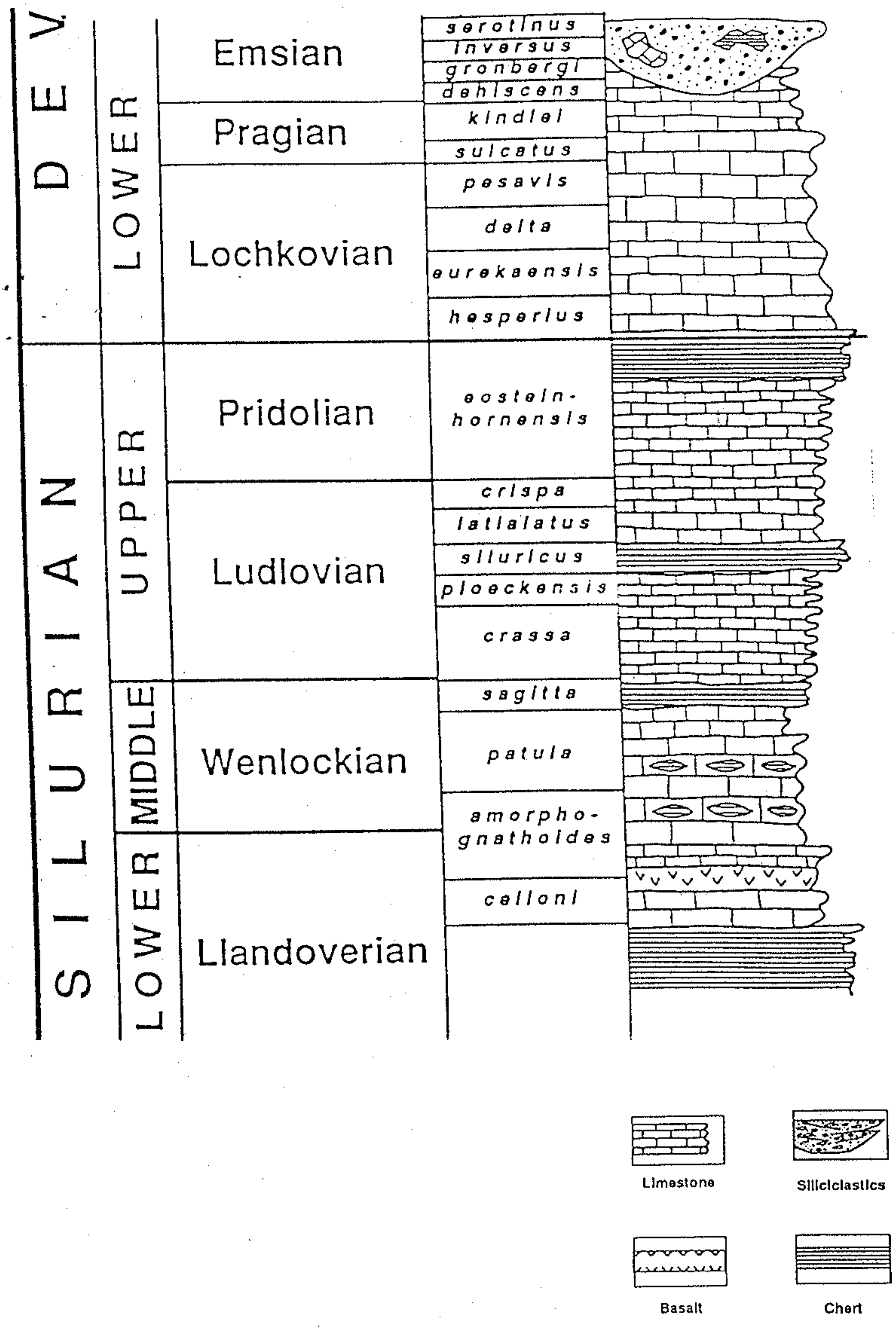
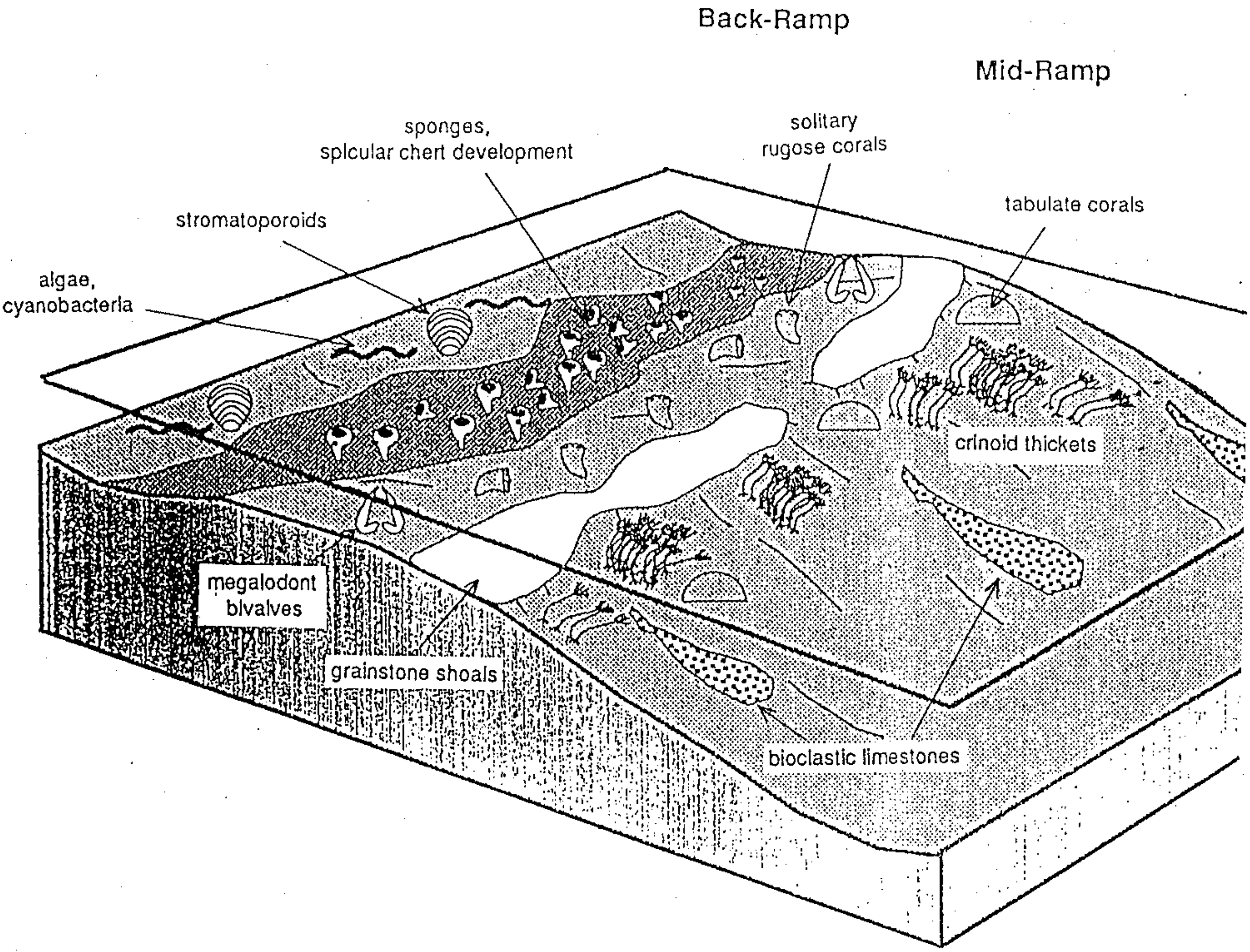


Fig. 3. Generalized stratigraphic sequence of the Chillagoe Formation in the Chillagoe - Mungana area (from Bernecker 1993).



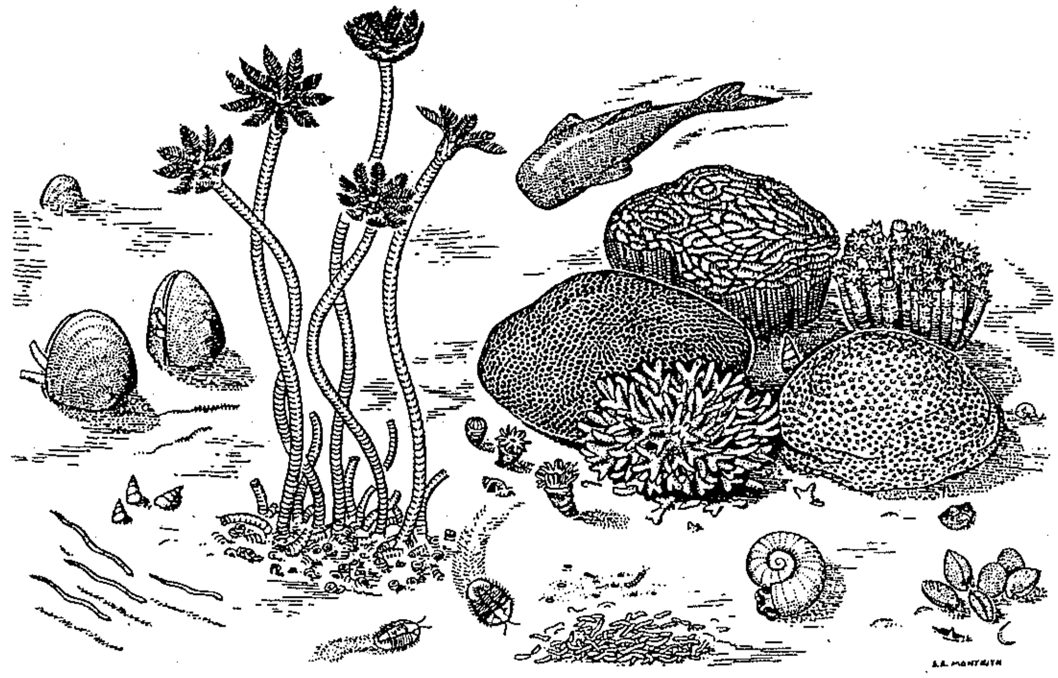
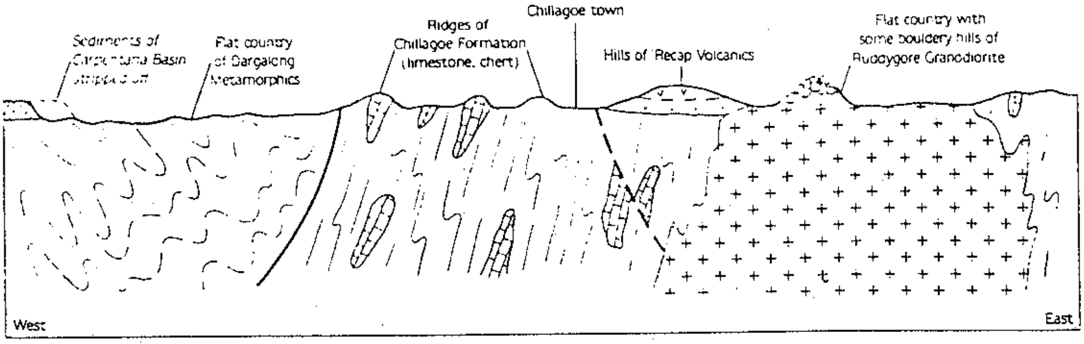
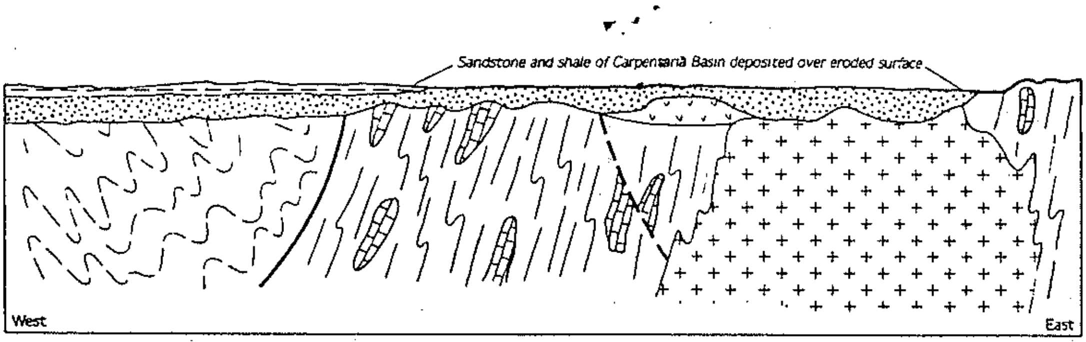


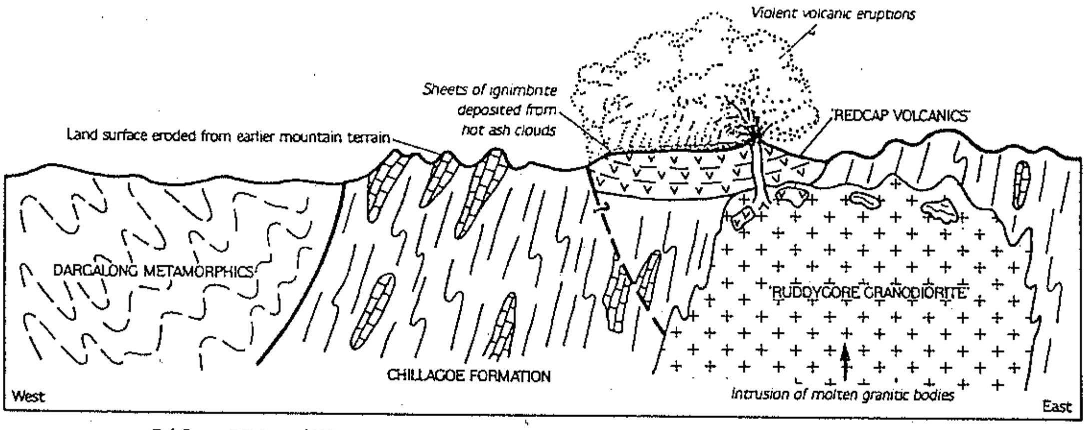
Fig. 4. Postulated environment of deposition of the Chillagoe Formation in Late Silurian time (from Bernecker 1993), with sketch showing the predominant life forms whose remains are found in the limestone (from Willmott and Tresize 1989).



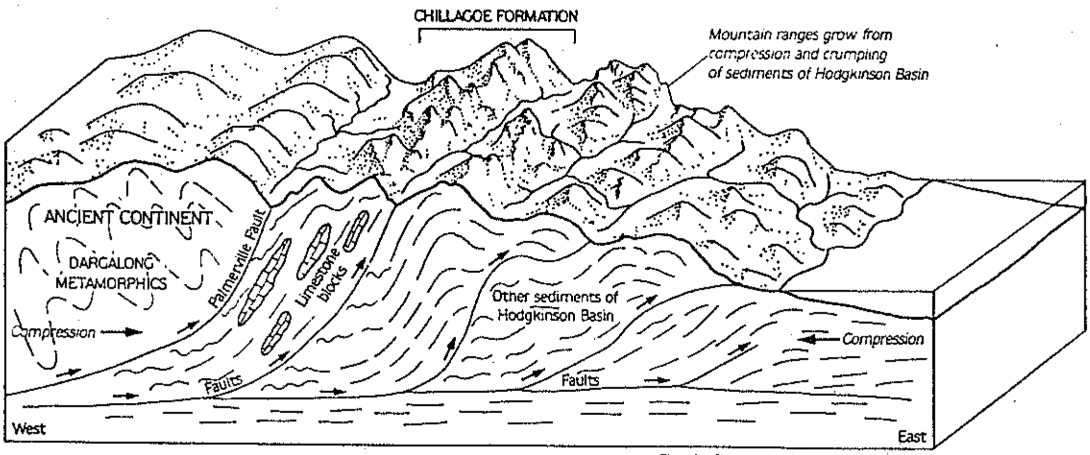
80 million years ago to present.



140 million years ago. Sediments of Carpentaria Basin blanket area.



310 - 270 million years ago. Violent volcanic eruptions, and intrusion of granitic rocks deep below the surface.



Sketch after work of R. Hammond JCUNQ

About 360 million years ago.

Fig. 5. Postulated geological history of the Chillagoe region from the Early Carboniferous to the present, after deposition in the Hodgkinson Province had ended (from Willmott and Tresize 1989).

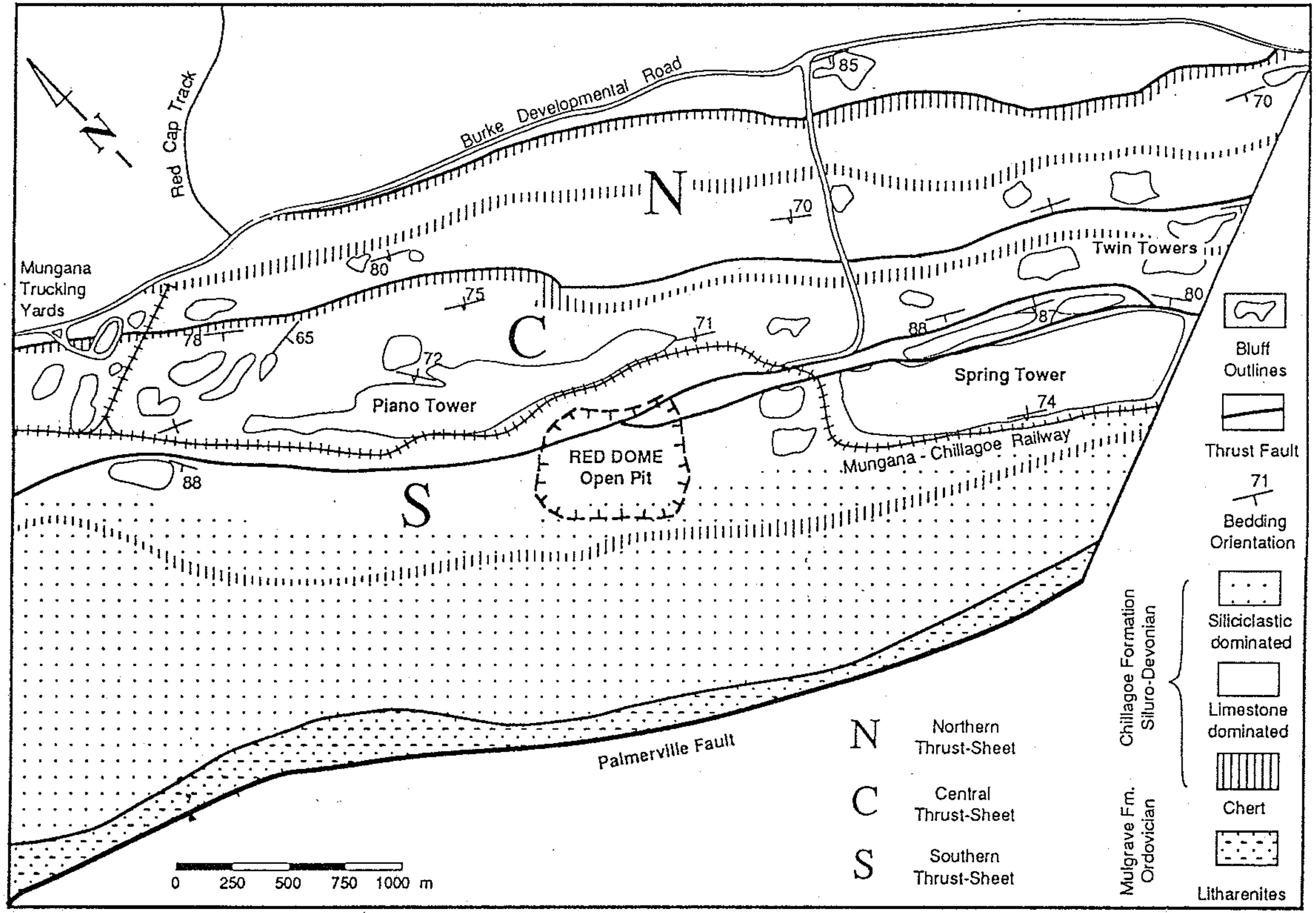


Fig. 6. Simplified geological map of the Mungana area, showing the thrust faults that repeat the stratigraphy (from Bernecker 1993).

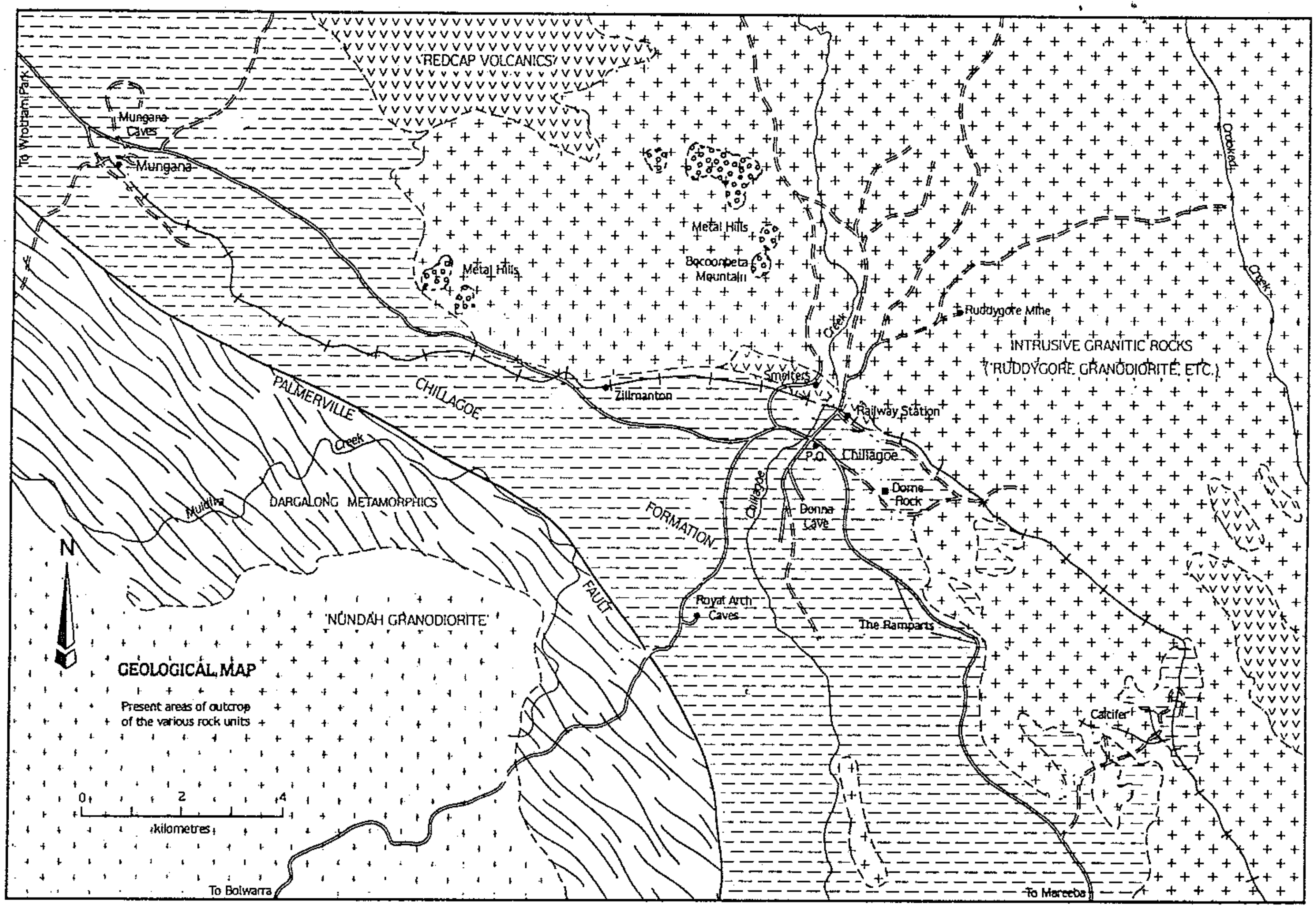


Fig. 7. Geological map of the Chillagoe - Mungana region (from Willmott and Tresize 1989).

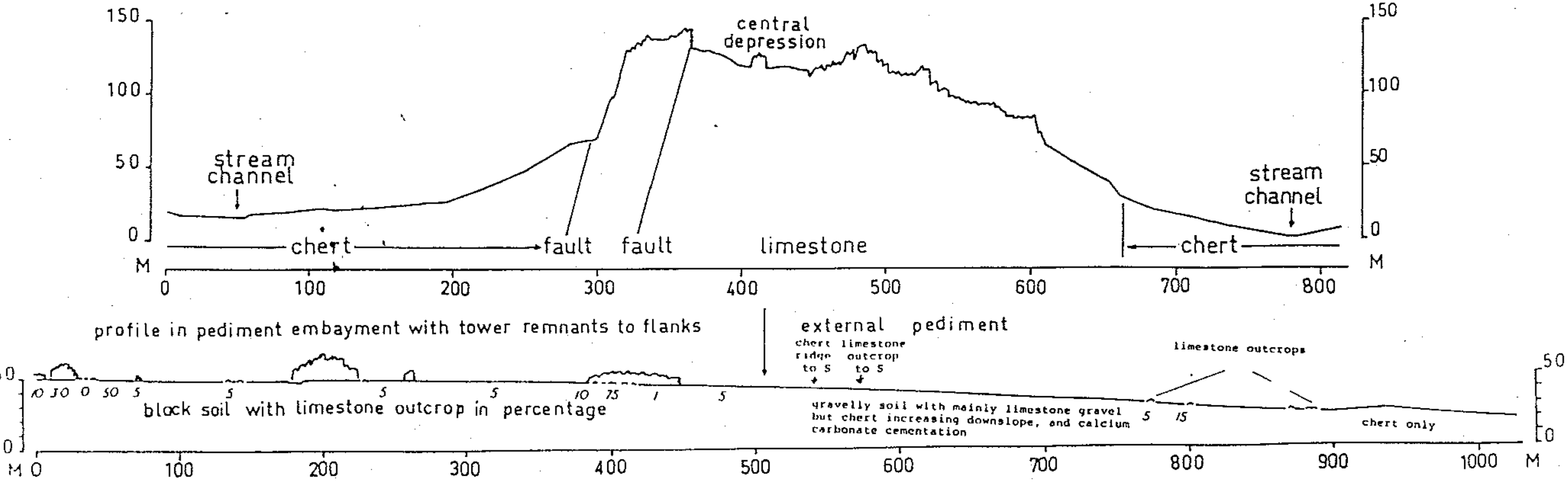


Fig. 9. Profiles of two limestone towers in the Mitchell-Palmer area north of Chillagoe, showing pediment development (from Jennings 1982).

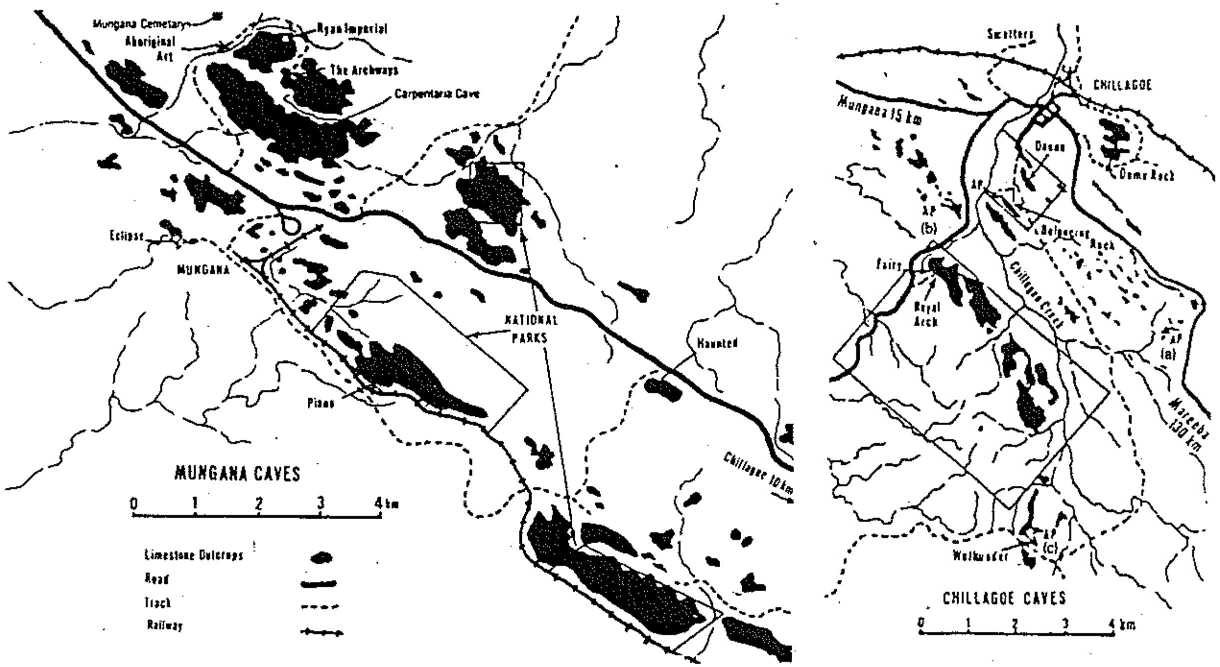


Fig. 8. Distribution of the main limestone towers in the Chillagoe - Mungan region (from Pearson 1987).

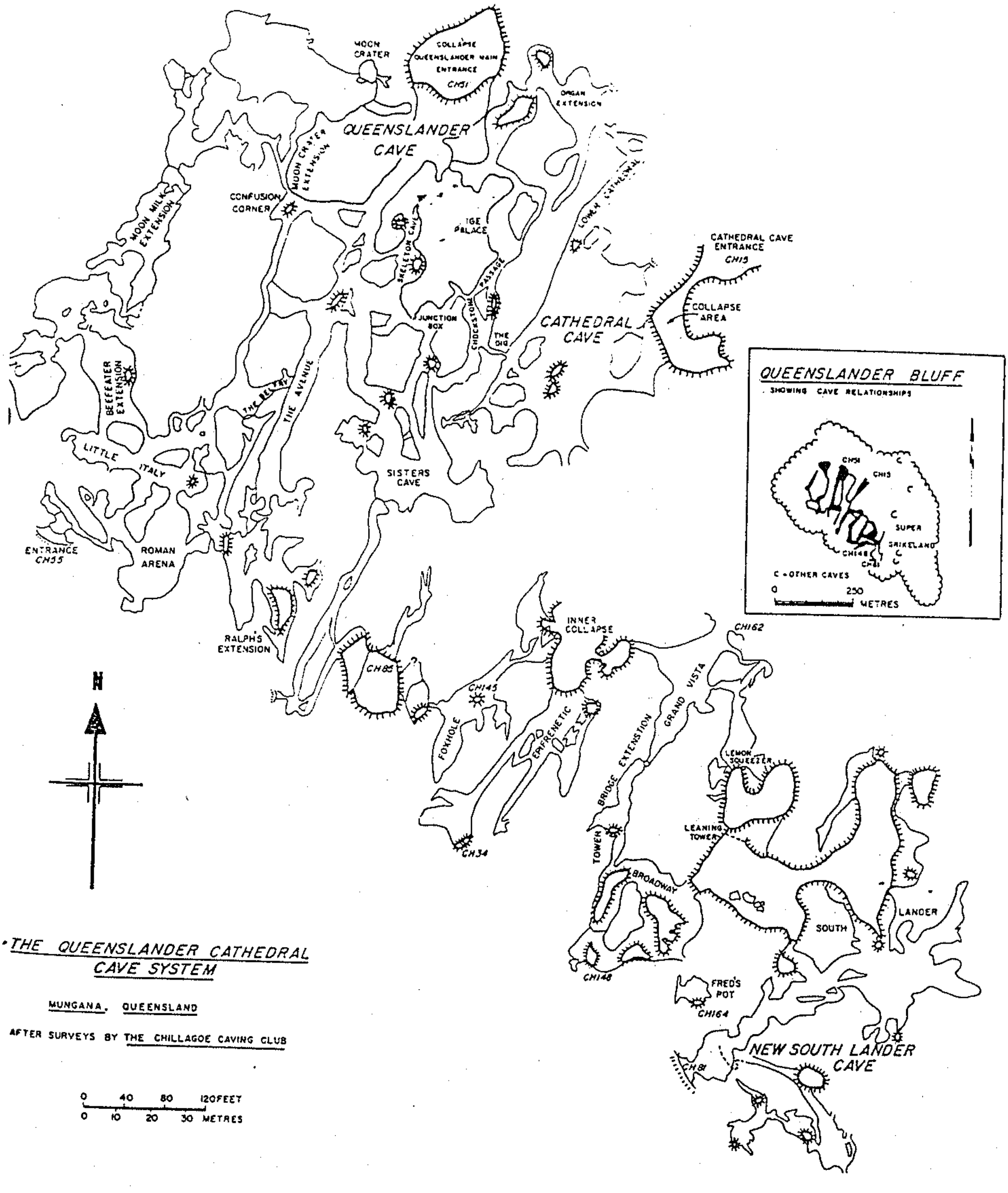


Fig. 10. Plan of the Queenslander cave system, Queenslander Tower (from Ford 1978).

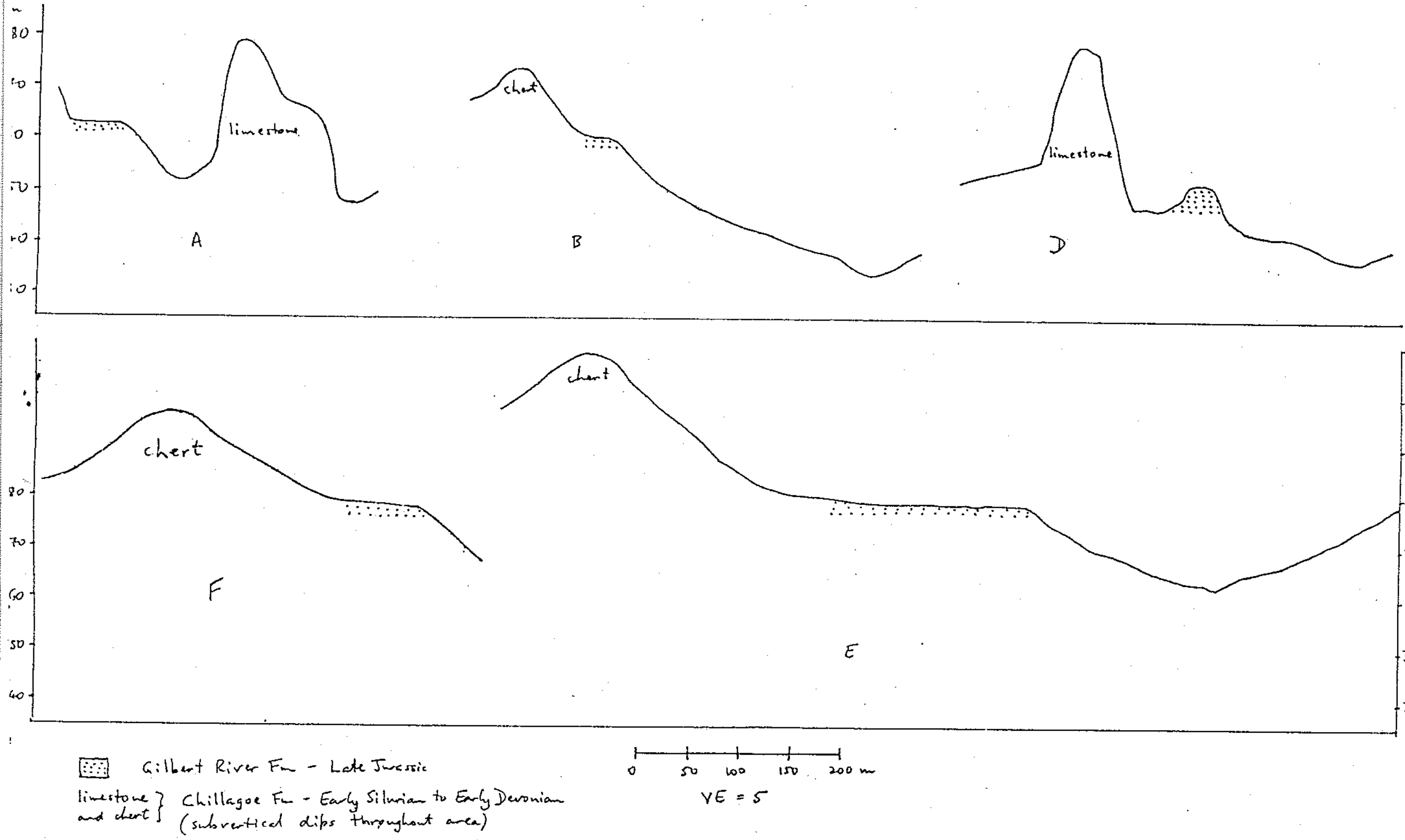


Fig. 11. Detailed cross-sections of 5 sites in the Mungana area, showing the relationship between the outcrops of Gilbert River Formation and the limestone towers and chert ridges.

7TH AUSTRALIA AND NEW ZEALAND GEOMORPHOLOGY GROUP CONFERENCE

FIELDTRIP

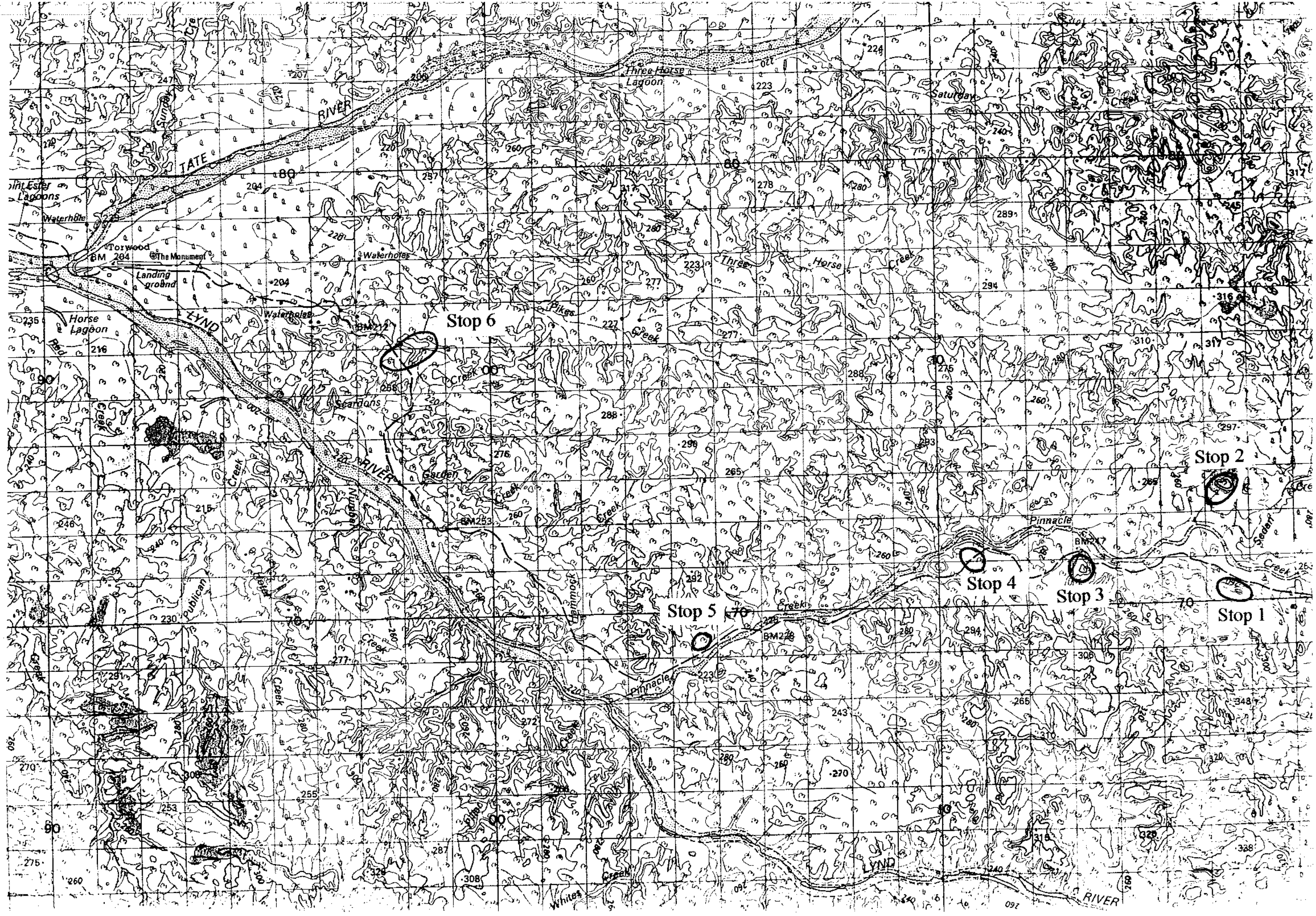
SUNDAY 6 OCTOBER 1996

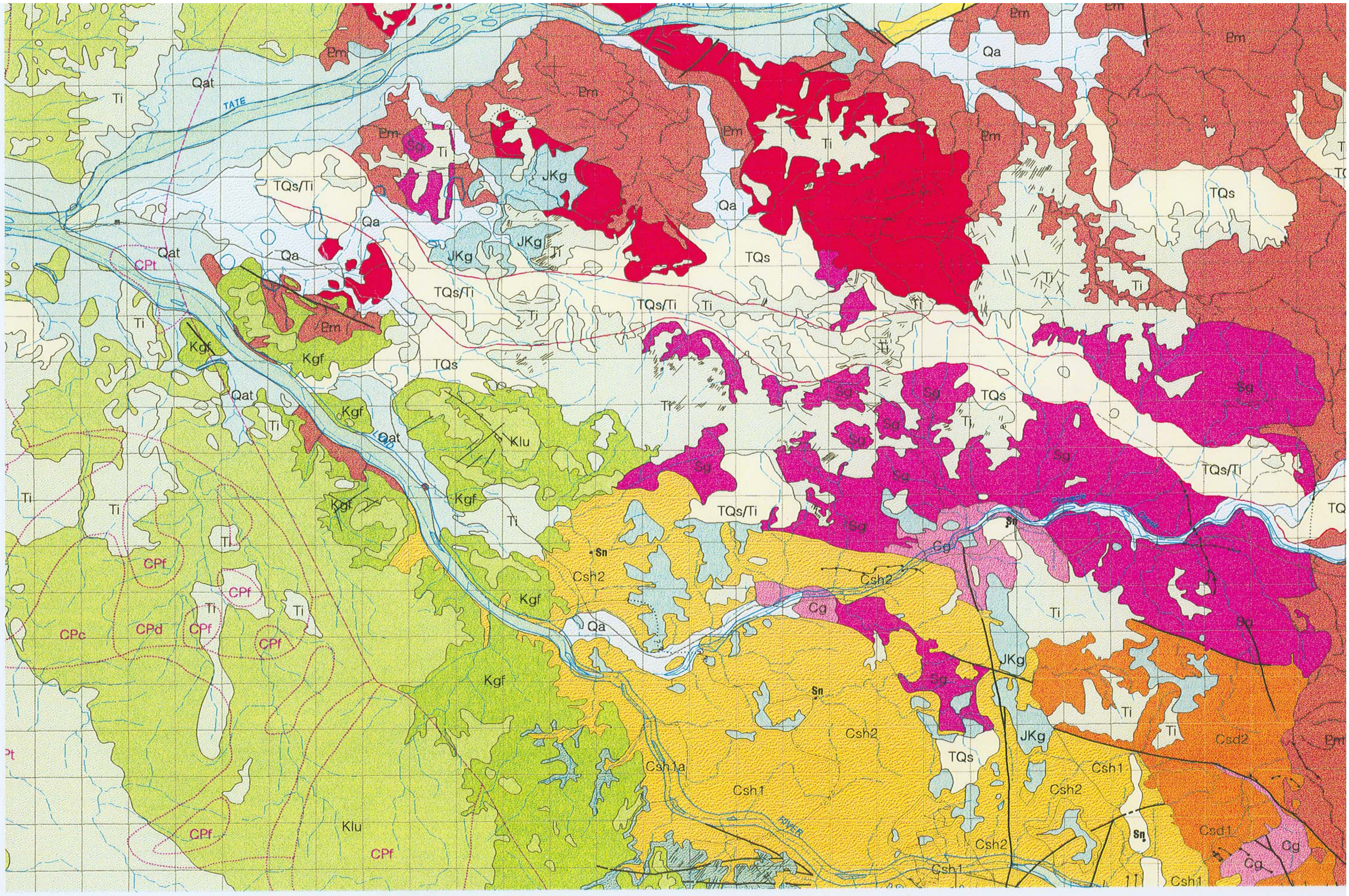
CHILLAGOE TO TORWOOD

Prepared by

Colin Pain

CRC for Landscape Evolution and Mineral Exploration
c/- Australian Geological Survey Organisation


Stop 1
Stop 2
Stop 3
Stop 4
Stop 5
Stop 6
TATE RIVER
LYND RIVER
Three Horse Lagoon
Saturday Creek
Three Horse Creek
Pikes Creek
Pinnacle Creek
Dammock Creek
Garden Creek
Number Ten Creek
Scardons
Horse Lagoon
Red Creek
Whites Creek
Sedan Creek
Torwood
BM 204
The Monument
Landing ground
Waterhole
Waterholes
BM212
BM253
BM228
BM217



TATE
Qat
Qa
Ti
TQs
TQs/Ti
Pm
Sg
JKg
Kgf
Klu
CPf
CPd
CPc
CPt
Cg
Csh1
Csh1a
Csh2
Csd1
Csd2
Sn
RIVER

Unlithified Units

QUATERNARY

- **Qa** — *Quartzose sand, gravel, silt, clay (undivided alluvium); Qll - Silt, clay and nodular ferricrete; deposits formed in shallow, seasonally inundated depressions and in swamps*
- **Qac** — *Quartzose gravel, sand, silt and clay (active channel alluvium); Qav - sand, silt, clay (levee deposits)*

Cainozoic Units

LATE TERTIARY TO QUATERNARY

- **TQs** — *Quartzose sand, some gravel, clay, silt and ironstone nodules; mainly residual; variably lithified and/or ferruginised in part; variably dissected*

Wyaaba Beds

MIDDLE TO LATE TERTIARY

- **Tmpy** — *Clayey quartzose sand and sandstone; granule to pebble gravel and conglomerate; sandy clay, calcareous mudstone; Tmpy2 - stream-channel sand, silt, gravel. Tmpy1 - clayey sand mudstone, granule gravel and conglomerate*

Bulimba Formation

EARLY TO LATE TERTIARY

- **Ti** — *Poorly indurated clayey quartzose sandstone to arkosic sandstone matrix, commonly pebbly; pebble conglomerate, sandy claystone; commonly ferruginised*

Rolling Downs Group

Wallumbilla Formation

EARLY CRETACEOUS

- **Klu** — *Dark grey to mottled cream, brick-red and purple (where weathered) marine mudstone and siltstone; ammonite and bivalve fossils abundant in places*

Gilbert River Formation

LATE JURASSIC TO EARLY CRETACEOUS

- **JKg** — *Medium to coarse quartzose sandstone, clay-cemented and pebbly in part; minor quartz-pebble conglomerate; siltstone; fine quartzose sandstone; variably ferruginous in part*
- **Kgf** — *Fine clay-rich quartzose sandstone; siltstone; minor mudstone; commonly bioturbated; fossiliferous (mostly bivalves) in part*
- **JKgy** — *Medium to coarse clay-cemented quartzose sandstone, mostly well sorted but pebbly in places; minor quartz-pebble conglomerate*

Unassigned intrusive rocks

Three Horse Lagoon Granite

EARLY PERMIAN?

- **Pgth** — *Porphyritic biotite granite and microgranite; biotite granite*

Scardons Volcanic Group

LATE CARBONIFEROUS TO EARLY PERMIAN

- **Csh2** — *Moderately lithics-poor to rich, crystal-rich rhyolitic ignimbrite; flow-banded rhyolite. Csh2a - lithics-rich, crystal-rich rhyolitic ignimbrite. Csh1,1a -massive, unwelded, lithics-rich crystal-rich hornblende? -biotite rhyolitic to dacitic ignimbrite; volcanic rudite; rhyolite*
- **Csd2** — *Lithics-rich, crystal-rich dacitic ignimbrite; moderately lithics-poor, crystal-rich rhyolitic ignimbrite volcanic rudite/breccia. Csd1 - moderately to poorly welded, lithics-rich, moderately crystal-rich rhyolitic to dacitic(?) ignimbrite; volcaniclastic rudite/breccia*

O'Briens Creek Supersuite

Cumbana Batholith

- **Cg** — *Miscellaneous unnamed biotite granites and porphyritic biotite granites*

White Springs Supersuite

SILURIAN

- **Sg** — *Variably porphyritic (epidote-)muscovite-biotite granite; biotite granodiorite and granite*

Nundah Granodiorite

- **Sgn** — *Medium to coarse-grained, seriate to porhyritic biotite-muscovite granodiorite*

Undivided metamorphic rocks

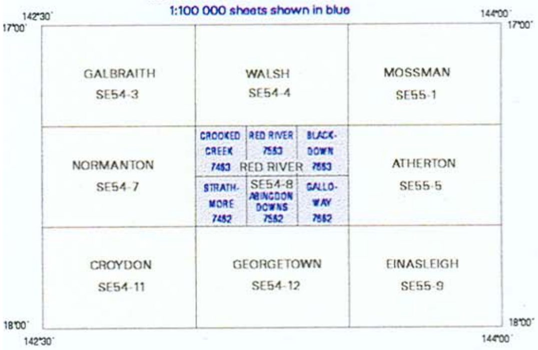
McDevitt Metamorphics

PALAEOPROTEROZOIC

- **Pm** — *Muscovite-biotite schist and gneiss; minor pegmatite and two-mica granite*

INDEX TO ADJOINING SHEETS

1:100 000 sheets shown in blue



BLACKDOWN

GEOLOGY

SHEET 7663

PRELIMINARY EDITION AUGUST 1996

SUBJECT TO AMENDMENT

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

DEPARTMENT OF MINES AND ENERGY

Introduction

The road from Chillagoe to Torwood crosses sediments of the Hodgkinson Formation (Devonian-Carboniferous) before passing onto granite, metamorphic and volcanic basement. The basement rocks are covered in part by Mesozoic sediments of the Carpentaria Basin. The Carpentaria Basin sediments and the basement are dissected, and are in turn covered in part by Karumba Basin sediments of Cainozoic age. The relationships between the rock units is complex. This trip will concentrate on Karumba Basin sediments and their relationships both to the underlying bedrock, and to landscape development in the area.

During the Mesozoic, mainly in the Cretaceous, a transgression resulted in marine sediments covering much of the area west of Chillagoe. Following emergence in the late Cretaceous the whole area underwent erosion and incision to produce a landscape with at least as much relief as at present. During this incision, the area around Torwood, and indeed most of the transition from basement to basin along the western side of the basement inliers of Cape York Peninsula, was a "cross over" zone between erosion in uplands to the east and deposition in fans and alluvial sequences to the west.

Cainozoic Sediments

Bulimba Formation

The oldest Cainozoic sediments in this area belong to the Bulimba Formation. This formation was originally thought to be Late Cretaceous-Early Tertiary (Smart et al. 1980), but recent unpublished mapping by GSQ and AGSO has revised the age to early to mid Tertiary. The formation consists mainly of medium to coarse to subangular sand, indicating a source moderately nearby. However, in places it contains much coarser material, especially in old channels. It has a discontinuous distribution along the western edge of the inliers on Cape York Peninsula, where it rests unconformably on both basement rocks, and Cretaceous Rolling Downs Group sediments. Further west it is more continuous, forming a dissected fan surface. It passes under the younger Wyaaba Beds to the west.

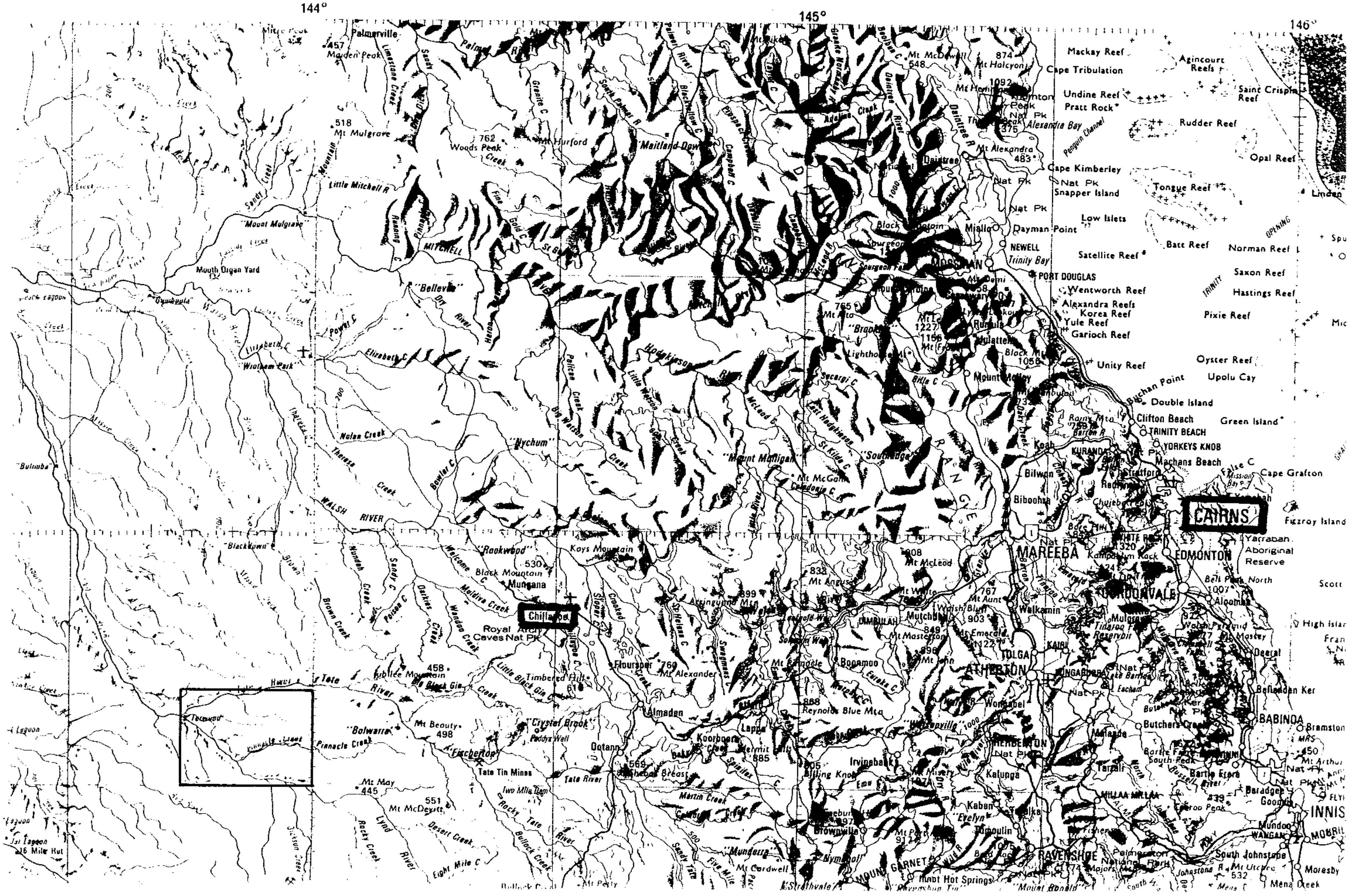
In the field trip area, Bulimba occurs in a number of landscape positions, from terrace remnants around and over some of the mesas, to low ridges that are probably channel fills. To the north of the road, the "Torwood Channel" is a very early part of the Bulimba Formation that has been extensively drilled during exploration for tin. To the north of the Torwood area Bulimba Formation is more continuous, with channels and gorges that cut down to basement.

Wyaaba Beds

The Wyaaba Beds are Miocene to Pliocene in age, and extend westwards from the Bulimba Formation as sandy, very low angle fan deposits. They consist mainly of large areas of sandy alluvium slightly dissected by numerous shallow and broad valleys. They have a distinctive pattern on airphotos, landsat images and maps. Although very little work has been done on the subject, the channel form and pattern suggests that some of the incision of the Wyaaba fans is caused by solution rather than physical fluvial erosion.

The Wyaaba Beds lie to the west of the area visited during the fieldtrip, west of the Lynd River.

AUSTRALIA SE 54



Claraville Beds

The Claraville Beds are of Plio-Pleistocene age, and represent a shift in fan deposition westwards from the Wyaaba fans. They consist of sand, fine sand and clay, and also have a distinctive pattern on images. Anastomosing channels, both active and inactive, cross the Claraville fans. In places there are long, sinuous and very low (1m) ridges of slightly coarser sand, covered with trees that stand out against the surrounding grassland. These ridges are clearly old channels that now stand out as positive relief, perhaps because the finer materials that surround them have compacted. The trees indicate they are still the location of subsurface water movement.

Quaternary/modern sediments

Within the area visited by the fieldtrip there are terrace and floodplain deposits along the main streams. These may correlated with come of the named beds discussed above, but no work has been done on this.

Further west, the Mitchell and Gilbert fans are still active, and inter-finger with and cover the coastal deposits, beach ridges and fore-dunes that lie adjacent to the Gulf of Carpentaria.

LANDFORMS

Landforms in the Torwood area consist of hills, plateaus, mesas and pediments, with small areas of river terraces and floodplains. The hills are formed mainly on basement volcanics and some granites. Flat lying Mesozoic sediments cap some plateaus and mesas, while other mesas are caped with indurated weathering profiles. Pediments slope at shallow angles away from the base of most mesas in the area.

WEATHERING ETC

In situ regolith in the area ranges from shallow soil profiles on bedrock to more highly weathered saprolite. There has also been some induration to form silcrete and siliceous hardpans.

Profiles

Most weathering profiles in the Torwood area are shallow, consisting of weakly developed sandy soils on saprolite or directly on bedrock. Regolith cover on most pediments is only a few tens of centimetres thick, often less than the average tent peg!

In a few places, on plateaus and mesa tops, there are deeper profiles with thin sandy top layers over mottled zone and saprolite materials up to a few tens of metres. Elsewhere on Cape York Peninsula deep weathering is confined to specific locations in the landscape - present valley floors, and old valley floors now in inverted relief. In the Torwood area there does not appear to be any deep weathering along present drainage lines, but the location of deep weathering on mesa tops, and the sometimes long and sinuous nature of these mesas, suggests relief inversion.

Induration

Induration plays an important role in landform and regolith development over the whole of Cape York Peninsula. The various hard pans and duricrusts that are found through the area are clear evidence that at least iron and silica are moved in solution from one part of the landscape to another. In this regard, both ferricrete and silcrete are locally very important parts of the regolith. Another obvious regolith material is the siliceous hardpan or "creek rock", that is found in many valley floors in many parts of north Queensland. This hardpan is a result of partial cementing of material by silica. It occurs in valley floors beneath and adjacent to channels. The cemented material is mainly alluvium, but in smaller channels weathered bedrock adjacent to the channel alluvium is also cemented. It can be quite young; we have a radiocarbon age of just over 1000 years for charcoal from within hardpan material out on a fan of Claraville Beds age. The origin of the hardpan seems to lie in the movement of silica in solution to the lowest parts of the landscape during wet seasons, and precipitation of the silica as the valley floors dry up during dry seasons.

In the Torwood area there are low sinuous ridges on silicified Bulimba Formation which are probably old channels now inverted. They may well have developed from the long sinuous ridges described for the Claraville Beds above.

Elsewhere on Cape York Peninsula silcrete occupies similar landscape positions, although it is not so widespread. Silcrete is also commonly associated with alluvial gravels and cobbles of well rounded quartz. It is tempting to equate the siliceous hardpan with an early stage in the development of silcrete.

LANDSCAPE EVOLUTION

The Torwood area lies in the cross-over zone between erosion and incision in the uplands to the east and deposition in the lowlands to the west. The highest parts of the landscape are mostly capped with Mesozoic sediments, including the Cretaceous Rolling Downs Group, so it is reasonable to suppose that they covered the whole area. However, by the time deposition of Bulimba Formation began sometime in the early Tertiary, the Mesozoic sediments had been dissected to about the same level as present dissection, exposing large areas of basement rocks. It is more difficult to relate the age of deep weathering and induration to the age of incision and then deposition of Bulimba Formation. However, one interpretation is that the deep weathering took place on a stable pre-incision low relief landscape, and that the remnants, most of which are silicified, are valley floors that are all that survive of this former land surface.

Deposition of the Bulimba Formation took place following this early incision. An early phase is represented by the Torwood channel, and slightly later phases by low sinuous ridges of silicified sand. Later phases are represented by low mesas, and by remnants of Bulimba Formation that drape and rarely cap mesas of basement or Mesozoic sediments. Thus during the deposition of Bulimba Formation the Torwood area would have been towards the apex of a fan that was one of a number of fans that extended up the western side of the Georgetown, Yambo and Coen Inliers. The Bulimba fan surface would have covered most if not all of the high parts of the Torwood area.

Following deposition of the Bulimba Formation the locus of deposition shifted further west, and the Torwood area was again dissected. In most places this consisted of stripping out Bulimba Formation and re-establishing the previous valleys. Much of the material derived from this stripping formed the Wyaaba Beds. This cycle was repeated when the Claraville Beds began deposition in the late Cainozoic.

The reasons for the shifts in location of fan activity along the western side of Cape York Peninsula are not clear. Dating is inadequate to establish correlations between known climatic fluctuations and fan activity. It may be that the gradual sinking of the Gulf of Carpentaria, as a result of sediment loading, caused slope or process thresholds to be crossed on the fans, thus interrupting what was essentially a continuous process.

This area, and indeed much of Cape York Peninsula, has great potential for further geomorphic research. It is, moreover, a great place to spend the southern winter.

BIBLIOGRAPHY

Bain, J.H.C., Mackenzie, D.E., Trail, D.S., Wellman, P., von Gnielinski, F.E., Dohrenwend, J.C. and Pain, C.F. 1996: Blackdown Geology, (1:100 000 scale preliminary edition map), Australian Geological Survey Organisation, Canberra.

De Deckker, P., Chivas, A.R., Shelley, J.M.G. and Torgersen, T., 1986: Palaeoenvironmental record of the Gulf of Carpentaria during the last 40,000 years based on ostracod shell chemistry, Sediments down under. 12th International Sedimentological Congress Abstracts,: 77.

De Deckker, P., Correge, T. and Head, J., 1991: Late Pleistocene record of cyclic eolian activity from tropical Australia suggesting the Younger Dryas is not an unusual climatic event, Geology, 19(6): 602-605.

Galloway, R.W., Gunn, R.H. and Story, R., 1970: Lands of the Mitchell-Normanby area, Queensland, CSIRO Land Research Series, 26: 101pp.

Grimes, K.G., 1972: A shallow artesian aquifer in the Tertiary deposits of southern Cape York Peninsula, Queensland Government Mining Journal, June 1972: 1-3.

Grimes, K.G., 1980: The Tertiary geology of north Queensland, Geology and geophysics of northeastern Australia. Henderson R.A. and Stephenson P.J. (eds), Geological Society of Australia, Queensland Division: 329-347.

Grimes. K.G., 1979: The stratigraphic sequence of old land surfaces in northern Queensland, BMR Journal of Australian Geology and Geophysics, 4: 33-46.

Grimes, K.G. and Doutch, H.F., 1978: The Late Cainozoic evolution of the Carpentaria Plains, North Queensland, BMR Journal of Australian Geology and Geophysics, 3: 101-112.

Grimes, K.G. and Doutch, H.F., 1979: The late Cainozoic evolution of the Carpentaria Plains, North Queensland: reply, BMR Journal of Australian Geology and Geophysics, 4: 79-81.

Jones, B.G., Burke, D.J., Senapati, N. and Hobday, D.K., 1986: A low gradient monsoonal sand-dominated fluvial system; the Gilbert River, Gulf of Carpentaria, Queensland, Sediments down-under: 12th international sedimentological congress: 157.

Jones, B.G., Nanson, G.C., Young, R.W., Senapati, N. and Bourke D.J., 1988: Channel avulsion and sand geometry in the Gilbert River fandelta, northern Queensland, Achievements in Australian geoscience. Abstracts Geological Society of Australia, 21: 207-208.

Jones, M.R. and Torgersen, T., 1988: Late Quaternary evolution of Lake Carpentaria on the Australia-New Guinea continental shelf, Australian Journal of Earth Sciences, 35(3): 313-324.

McConachie, B.A., Filatoff, J. and Senapati, N., 1990: Stratigraphy and petroleum potential of the onshore Carpentaria Basin, Queensland, APEA Journal, 30(1): 149-164.

McConachie, B.A., Stainton, P.W., Barlow, M.G. and Dunster, J.N., 1994: The offshore Carpentaria Basin-Gulf of Carpentaria, North Queensland, APEA Journal, 34(1): 614-625.

Nanson, G. C., Young, R. W., Price, D. M. and Rust, B. R., 1988: Stratigraphy, sedimentology and late Quaternary chronology of the channel country of western Queensland, In Warner, R. F. Fluvial geomorphology of Australia. Academic Press, Sydney: 151-175.

Nanson. G.C., Price, D.M., Short, S.A., Young, R.W. and Jones, B.G., 1991: Comparative Uranium-Thorium and Thermoluminescence dating of weathered Quaternary alluvium in the tropics of northern Australia, Quaternary Research, 35: 347-366.

Pain, C.F. and Ollier, C.D., 1992: Ferricrete in Cape York Peninsula, North Queensland, BMR Journal of Australian Geology and Geophysics, 13: 207-212.

Pain, C.F. and Wilford, J.R., 1992: Ebagoola regolith-landforms. Australia 1:250 000 Regolith-Landform Series. Sheet SD54-12, preliminary edition, Bureau of Mineral Resources, Geology and Geophysics. Canberra.

Pain, C.F., Wilford, J.R. and Dohrenwend, J.C., 1994: Regolith-landforms of the Ebagoola 1:250 000 sheet area, (SD54-12), North Queensland, AGSO Record, 1994/7: 38pp.

Rhodes, E.G., 1982: Depositional model for a chenier plain, Gulf of Carpentaria, Australia, Sedimentology, 29(2): 201-221.

Rhodes, E.G., Polach, H.A., Thom, B.G. and Wilson, S.R., 1980: Age structure of Holocene coastal sediments; Gulf of Carpentaria, Australia, Radiocarbon, 22(3): 718-727.

Simpson, C.J. and Doutch, H.F., 1977: The 1974 wet-season flooding of the southern Carpentaria Plains, northwest Queensland, BMR Journal of Australian Geology and Geophysics, 2: 43 - 51.

Smart, J., 1976: The nature and origin of beach ridges, western Cape York Penisula, Queensland, BMR Journal of Australian Geology and Geophysics, 1: 211-218.

Smart, J., 1977: Late Quaternary sea-level changes, Gulf of Carpentaria, Australia, Geology, 5(12): 755-759.

Smart, J., Grimes, K.G., Doutch, H.F. and Pinchin, J., 1980: The Mesozoic Carpentaria Basin and the Cainozoic Karumba Basin, North Queensland, Bureau of Mineral Resources, Geology and Geophysics, Bulletin, 202: 73pp.

Torgersen, T., Hutchinson, M.F., Searle, D.E. and Nix, H.A., 1983: General bathymetry of the Gulf of Carpentaria and the Quaternary physiography of Lake Carpentaria, Palaeogeography, Palaeoclimatology, Palaeoecology, 41(3/4): 207-225.

Torgersen, T., Luly, J., De Deckker, P., Jones, M.R., Searle, D.E., Chivas, A.R. and Ullman, W.J., 1988: Late Quaternary environments of the Carpentaria Basin, Australia, Palaeogeography, Palaeoclimatology, Palaeoecology, 67(3-4): 245-261.

Twidale, C.R., 1956: A reconnaissance survey of the coastline of the Leichhardt-Gilbert area of north-west Queensland, Australian Geographer, 6(5): 14-20.

Twidale, C.R., 1956: Chronology of denudation in northwest Queensland, Bulletin of the Geological Society of America, 67: 867-882.

Wasson, R.J., 1979: The late Cainozoic evolution of the Carpentaria Plains, North Queensland: a discussion, BMR Journal of Australian Geology and Geophysics, 4: 77-78.

SITES ON BLACKDOWN 1:100 000 SHEET, ALONG ROAD FROM EAST

There are no stops on the way out, except to open gates. We will have lunch at the Lynd River, and play the rest by ear, keeping an eye on the time.

Stop 1

Site is a mesa south of the road. 5m silicified mottled zone on moderately weathered granite.

Stop 2

1 km north of Pinnacle Creek. We may have to walk to this one. The site is on the Torwood channel.

Stop 3

Mesa south of the road. The mesa is a mixture of volcanics and granite, with Bulimba Formation on the side and towards the top.

Stop 4

Low ridge of silicified Bulimba Formation.

Stop 5

Just north of road. 3m ridge of Ti surrounded by alluvium in Pinacle Creek terrace.

Stop 6

Mesas on both sides of road, with Ti draped over them. Bedrock is very highly weathered and silicified volcanics. (Depending on time, we may miss this one.)