NATURAL HERITAGE VALUES of the CHILLAGOE and MITCHELL-PALMER KARST and CAVES

David Gillieson
College of Marine & Environmental Sciences, James Cook University, Cairns Qld 4870, Australia.
Email:dsgillieson@gmail.com

Editor's note: This paper was published in the *North Queensland Naturalist* and is reproduced here with its permission. ACKMA thanks the publishers for this permission. If citing this paper, the original publication must be used.

Citation: Gillieson D. 2016. Natural heritage values of the Chillagoe and Mitchell-Palmer karst and caves. *North Queensland Naturalist* 46: 71-85

Abstract

Karst (limestone) landforms and associated features such as caves are distributed widely throughout the world. They have many natural heritage values and many are located in protected areas including several which are on the World Heritage List. In North Queensland, two areas notable for their karst geoheritage values have been evaluated as part of the National Heritage List process. The karst towers or bluffs at Chillagoe extend over a considerable distance and achieve heights of up to 65 m above the surrounding undulating terrain. Further north, the karst towers at the Mitchell-Palmer area achieve greater heights and extend over a distance of 80 km between the Mitchell and Palmer rivers. Tower karst is an unusual landscape type in Australia, with clearly the best examples found in the Chillagoe Karst Region. They may be potentially significant at a global level with the closest comparisons being in Cuba and Madagascar. Over 1000 caves have been recorded in the towers, and contain unusual calcite formations, fossil bone deposits and unique copper sinter deposits. A National Heritage List nomination for the Chillagoe and Mitchell-Palmer karst areas was submitted in 2009. The proposed boundaries of the Heritage place were adjusted to avoid current mining leases, reducing the total area by around 50%. The Australian Heritage Council has now assessed the Chillagoe Karst Region and has identified that the Chillagoe Karst Region (including parts of the Mitchell-Palmer Karst Belt) meets the National Heritage criteria for its outstanding karst limestone bluffs, towers and cave development. The Council's assessment was made available for public review and comment until November 2015, and following this the assessment and comments are now with the Minister for the Environment for a final decision. Current environmental issues include fire management, weed control, feral animals and the impacts of mining.

Introduction

Along the length of the the Eastern Highlands of Australia, from Tasmania to North Queensland, there are karst areas with caves developed in hard limestones of Ordovician to Permian age. As well as caves there are well-developed karst hydrologic systems, springs, dolines and other landforms. Other values of these karsts include highly significant palaeontological and biological aspects.

West of Cairns there are extensive Silurian limestone areas running in an arc from Chillagoe to the northwest and then north into the wild country between the Mitchell and Palmer Rivers. These karst areas have a high degree of biophysical integrity and are the best examples of tropical tower karst in Australia. Some of the Chillagoe towers are protected under National Park status, while the Mitchell-Palmer karsts are on remote pastoral properties and access is restricted by the owners. This paper describes some approaches to the assessment of cave and karst heritage in Australia, and applies these approaches to an evaluation of the natural heritage of the Chillagoe and the Mitchell-Palmer karsts of north Queensland.

Chillagoe is a small town located about 200 km west of Cairns in tropical north Queensland. Lying to the west of the Great Dividing Range, the perennial Mitchell and Palmer rivers drain the area to the Gulf of Carpentaria. The Mitchell-Palmer karst extends for 100 km between those two rivers in remote terrain accessible only by minor tracks. The region has a tropical monsoonal climate with an annual average rainfall of 830 mm, most of which falls in the short wet season from December to March. Daily maximum temperatures frequently exceed 38°C in the wet season and over 25°C in the dry season. The dominant vegetation of the area is a savanna woodland with various eucalypts including bloodwoods. Along streams and on the limestone, semi-deciduous vine forest and vine thicket dominate with figs, eucalypts and paperbarks as emergents. The dominant land uses are extensive cattle grazing and minor quarrying of the limestone for lime and building stone.

Chillagoe and the Mitchell-Palmer karst lie within the Eastern Australian Province, characterised by steeply dipping rocks forming narrow ridges extending along the strike (Gillieson 2004). The Silurian limestones are a series of marine deposits that were laid down along the continental shelf 420–360 million years ago. The limestone forms prominent and spectacular karst towers up to 65 m high near Chillagoe, and are separated by lower, undulating terrain formed on sedimentary deposits (chert, sandstone) and volcanic ridges. The ridges and towers run in a NW–SE direction near Chillagoe and more northerly in the Mitchell-Palmer Karst (Fig. 1). The towers are typically lens-shaped, up to 1 km long and 300–400 m wide. Detailed mapping around Mungana has shown that the towers are separated by thrust faults.

There are over a thousand caves recorded and mapped in the Chillagoe and Mitchell-Palmer karsts (Chillagoe Caving Club 1982). The longest is the Queenslander Cave, which attains a length of over 6 km and consists of a joint-controlled maze. Few cave entrances are known from the pediments, and most caves are entered from the upper surfaces of the towers or from the angle between the cliffs and the pediments. The dominant passage shapes are rifts that narrow upwards and may intersect the surface producing small daylight holes in the roof. Larger chambers 30–50 m wide are located at joint intersections and may connect upwards with clefts, giving daylight chambers.

A

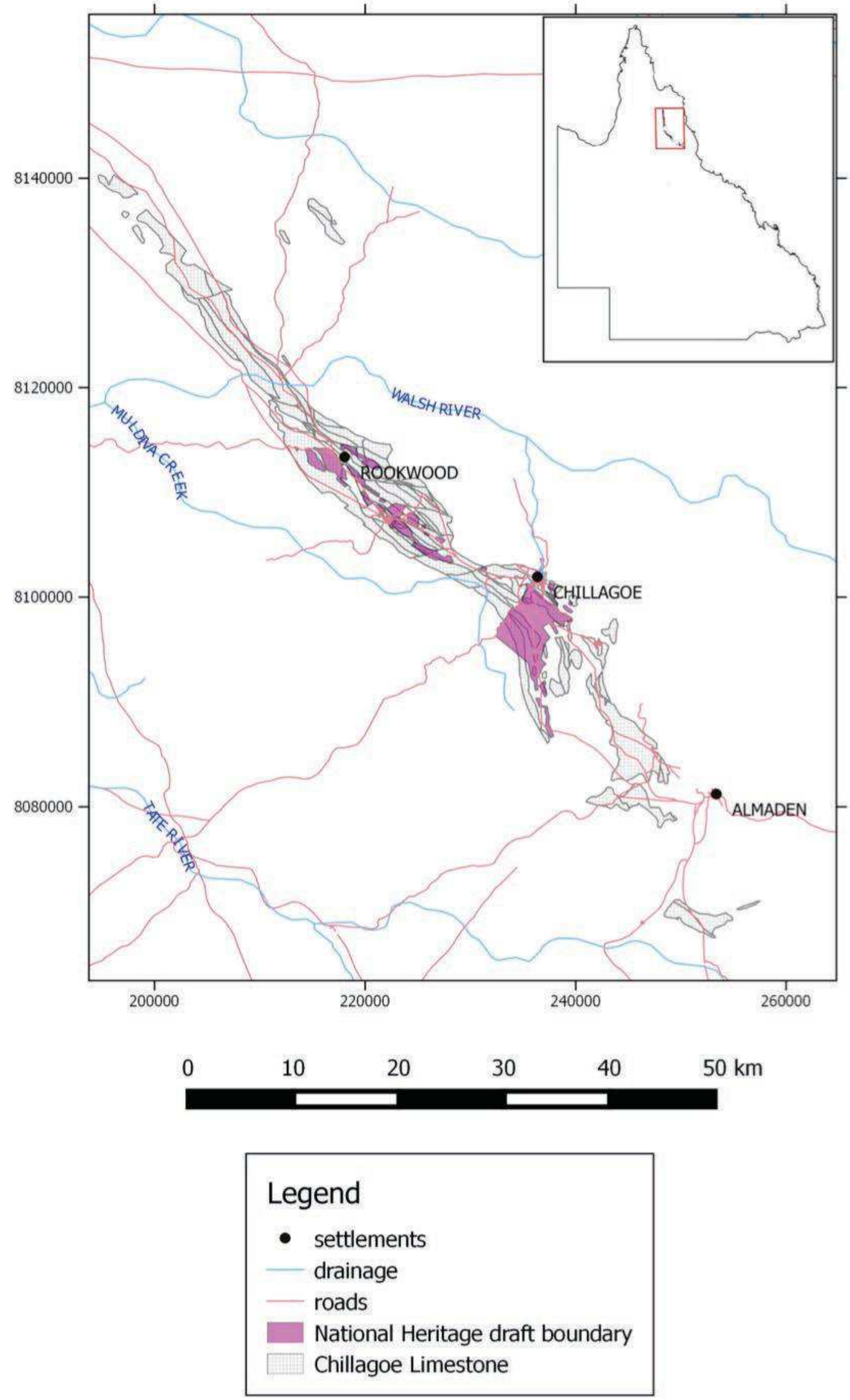

Figure 1. Extent of the Chillagoe (A) and Mitchell-Palmer (B – next page) karsts, with proposed National Heritage List boundaries (2015).

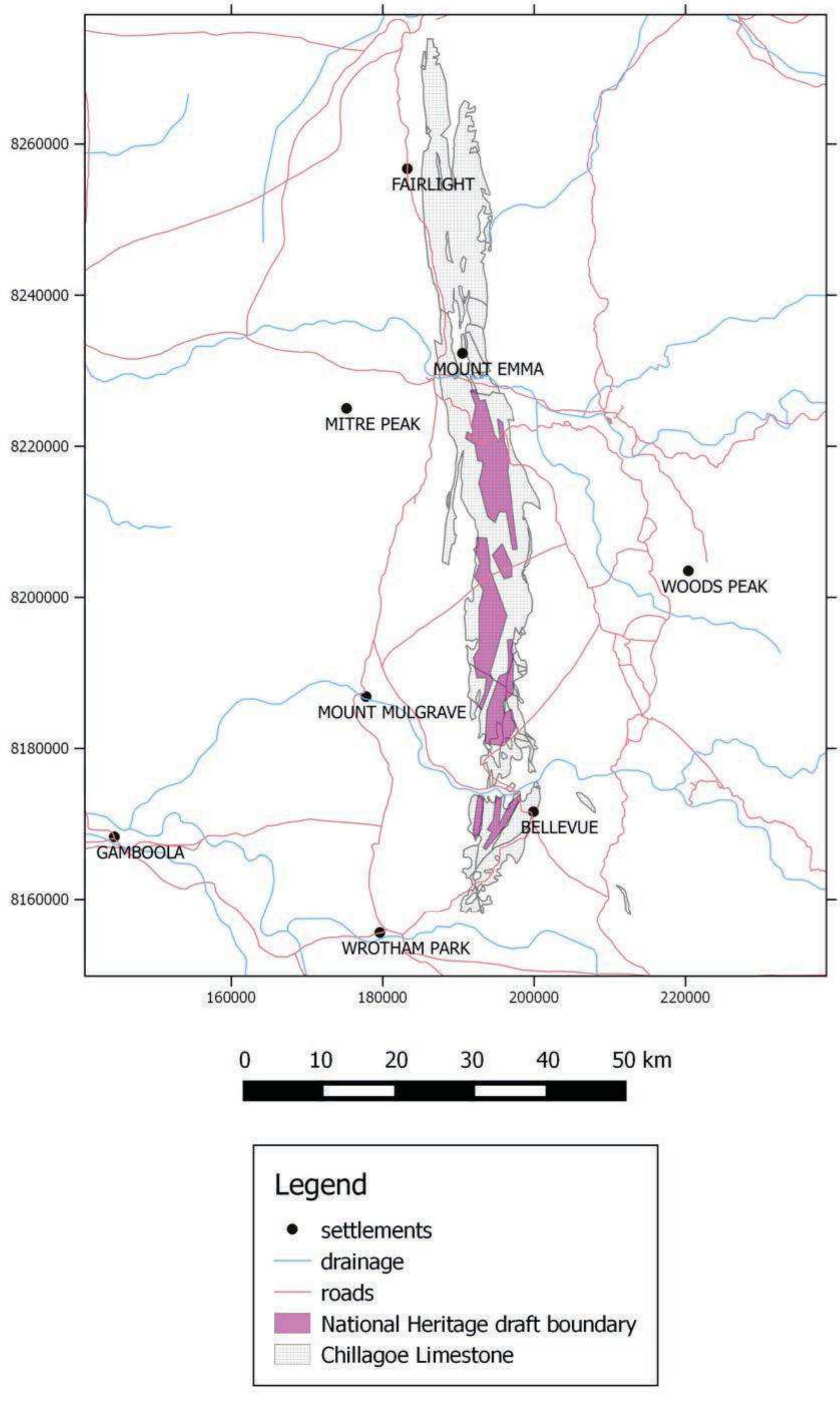
8260000
8240000
8220000
8200000
8180000
8160000
160000
180000
200000
220000
FAIRLIGHT
MOUNT EMMA
MITRE PEAK
WOODS PEAK
MOUNT MULGRAVE
BELLEVUE
GAMBOOLA
WROTHAM PARK
0
10
20
30
40
50 km
Legend
settlements
drainage
roads
National Heritage draft boundary
Chillagoe Limestone

Figure 1b.

Approaches to assessing cave and karst geoheritage values in Australia

Karst landforms and associated features such as caves are distributed widely throughout the world. They have many geoheritage values and many are located in various protected areas, including several which are on the World Heritage List (e.g. South-West Tasmania, Blue Mountains, Purnululu). The direct values of geological, landform and soil systems to humans, as our 'geoheritage', are the reasons most frequently cited to justify geoconservation, and these are indeed important reasons to value geodiversity.

Geoheritage comprises those elements of natural geodiversity which are of significant value to humans but do not involve the depletion or degradation of those elements (Houshold et al. 1997; Sharples 2002). The import of this definition is that it implies a distinction between the utilitarian resource values derived from the removal, processing or manipulation of rocks, landforms and soils by means such as mining, engineering or agriculture, and the conservation values of rocks, landforms and soils as heritage in their natural state.

Geoheritage may be of value to humans as:

- providing scientific evidence of the past development of the Earth, and of the evolution of life on Earth;
- sites of importance for research and education;
- features which inspire us because of their aesthetic qualities;
- features of recreational or tourism significance (eg. mountains, cliffs, caves, beaches, etc.);
- features which form the basis of landscapes that have contributed to the 'sense of place' of particular human communities; and
- features which play a role in the cultural or spiritual values of human communities (e.g. sacred caves and mountains).

Each of these points can form a theme or themes which can be developed and used to compare sites as part of a process of inscription on a heritage list such as the National Heritage List and World Heritage list. In 2006 the Federal Government Department of Environment convened a workshop to identify the most significant karst sites in Australia, and assess their values and significance. This was a precursor to listing some sites on the National Heritage List. The sites were discussed in broad groups to reflect karst 'types', which developed in different climatic and physiographic regimes. Within each type, karst sites have similar characteristics or developmental history; however each karst area or site also has unique aspects. The delineation of broad types gives a basis for comparison for many, but not all, of the features and values found in karst landscapes. Types included:

- Temperate Eastern Highland impounded karsts;
- Monsoonal tropical karsts;
- Southern Tertiary basin karsts;
- Coastal zone karsts;
- Island karsts; and
- Karsts of the arid zone.

Some karsts fall into more than one category (for example: the Chillagoe and Mitchell-Palmer karst area is part of the Eastern Highland impounded karsts, as well as representing a monsoonal tropical karst). Nevertheless, these groupings provided a useful starting point in which to highlight and compare values. Further to the identification of characteristics inherent within each broad type, a matrix was developed during the workshop which set out a series of heritage themes against which cave and karst values could be grouped, highlighted and compared, and within each major type. The themes fell into two main categories, each with a number of subcategories (Table 1). Note that the detailed consideration of fossil sites was excluded from consideration under the geodiversity category, although fossil values were noted where known. This was part of a separate exercise.

The practical implementation of geoconservation requires that significant elements of geodiversity – those requiring special management prescriptions – be identified on the ground through a process of inventory. The most detailed approach to developing systematic thematic inventories involves:

- developing or adopting a classification scheme for a theme under consideration;
- using available data and further fieldwork as necessary to identify all known examples of each classified group within a defined study area; and
- comparing the known examples in each classified group to identify which are the best expressed or developed examples of their type.

Table 1. Potential heritage themes for karst landscapes, as developed at a Department of Environment workshop.

Theme categories	Theme sub-categories
Geodiversity	• the evolution of Australia's geodiversity • presence of palaeokarst and multi-phase caves • complexity of the hydrology • bedrock type and complexity • karst geomorphology • importance for research
Biodiversity	• importance in illustrating evolutionary processes • importance as refugia • consideration of biogeography and isolating factors • species diversity • importance for research

There are a number of classification schemes in use for cave and karst geoheritage. Grimes (1995) has developed a broad scheme of geological and geomorphological types that can be used at a regional or national level. At the level of the individual cave, it is important to recognise that the values can fall into three main categories: geological, biological or cultural. An essential first step in the assessment of geological heritage is the compilation of a cave inventory. Any cave inventory should first consider the context in which the cave occurs. Thus the cave needs to be placed in its relationship with local geology and geomorphology and the extent to which it presents any typical or unusual features such as a cave developed in fault gangue, or a mineralized void related to skarn rocks. The second task is to compile an inventory of the cave contents. This should include the type and extent of calcite formations or speleothems, sediment deposits and bone deposits, water bodies, cave solutional features such as pendants and anastomosing tubes, rare or unusual minerals. Any natural hazards should also be noted at the time. Cave mapping is a very useful adjunct to record special features, determine potential impacts of either future visitors or local economic developments. A set of accepted symbols endorsed by the International Speleological Union is used for mapping, coupled with accepted survey accuracy grades. In Australia, the Australian Speleological Federation has published a Karst Index (Matthews 1985) which is maintained online and contains data on over 10,000 caves in Australia. The Index also has details of many cave maps that have been produced and curated by individual clubs such as the Chillagoe Caving Club. The Index does provide a basis by which individual caves and karst sites can be classified and then compared for geoheritage evaluation. Similarly there is a State karst inventory for Tasmania and New South Wales. In all cases a proforma based on a classification scheme is used for recording basic data.

Karst areas may have sufficient significance to be inscribed on a Heritage List. The National Heritage List was established to recognise places of outstanding heritage significance to Australia. National Heritage listing does not change land tenure or ownership, and is not the same as an area becoming a National Park. If a place is listed the National Heritage values will be protected under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). Approval under the EPBC Act is required for any action that could have a significant impact on the National Heritage values of a listed place.

Key tools used to decide a place's heritage significance are criteria and thresholds. Criteria are a collection of principles or characteristics used to help decide if a place has heritage values. There will usually be several criteria that might be applied to a place being considered:

(a) the place has outstanding heritage value to the nation because of the place's importance in the course, or pattern, of Australia's natural or cultural history;

(b) the place has outstanding heritage value to the nation because of the place's possession of uncommon, rare or endangered aspects of Australia's natural or cultural history;

(c) the place has outstanding heritage value to the nation because of the place's potential to yield information that will contribute to an understanding of Australia's natural or cultural history;

(d) the place has outstanding heritage value to the nation because of the place's importance in demonstrating the principal characteristics of: (i) a class of Australia's natural or cultural places; or (ii) a class of Australia's natural or cultural environments;

(e) the place has outstanding heritage value to the nation because of the place's importance in exhibiting particular aesthetic characteristics valued by a community or cultural group;

(f) the place has outstanding heritage value to the nation because of the place's importance in demonstrating a high degree of creative or technical achievement at a particular period;

(g) the place has outstanding heritage value to the nation because of the place's strong or special association with a particular community or cultural group for social, cultural or spiritual reasons;

(h) the place has outstanding heritage value to the nation because of the place's special association with the life or

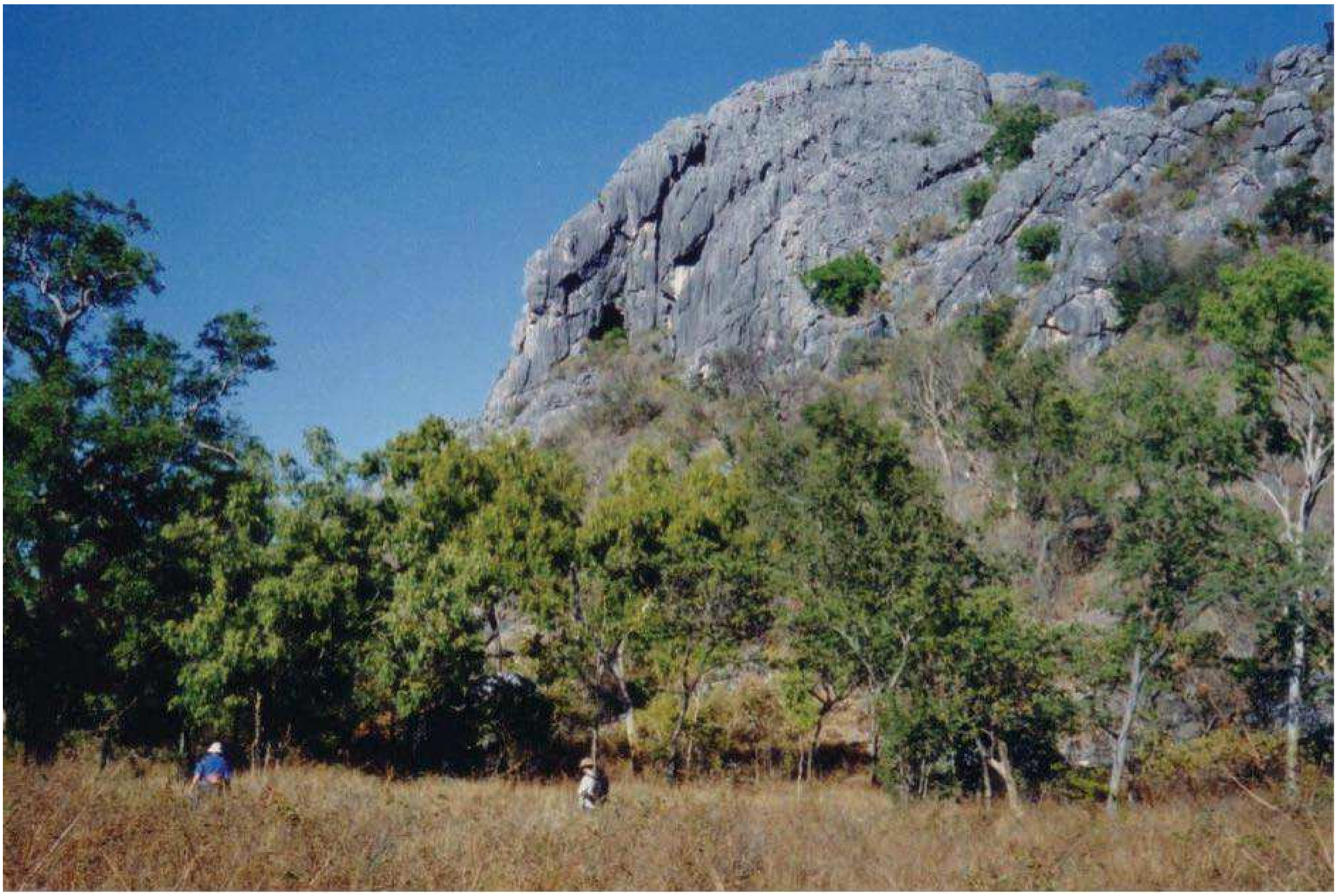

Figure 2. Mordor Bluff at the Mitchell-Palmer karst. This limestone tower is approx. 100m high above the surrounding chert plains. Photo: David Gillieson.

works of a person, or group of persons, of importance in Australia's natural or cultural history; or

(i) the place has outstanding heritage value to the nation because of the place's importance as part of Indigenous tradition.

Thresholds relate to the level or ranking of the heritage values that a place must possess in order to be placed on a heritage list. Usually a comparative analysis of similar places in Australia needs to be carried out. Criteria of integrity and authenticity of the place may also be important. Threshold determination may also need to rely heavily on relevant experts with access to a range of unpublished literature or relevant data. Although there are tools for assessing the biological values of a place, until recently there has been no comparable tool for comparative analysis of geological or geomorphological values. White and Wakelin–King (2014) have developed a semi-quantitative methodology for this purpose. The Earth Sciences Comparative Matrix (ESCoM) groups sites in process themes. Each site is assessed against National Heritage criteria and compared with other similar places according to their degree of unusualness, integrity, and authenticity. A site scoring well across multiple themes has increased heritage significance. The overall values of a site are quantified, leading to a ranking which enables a qualitative judgement on whether it achieves the threshold of outstanding heritage value. Gap analyses are a well-tested method for comparative analysis of a suite of possible sites (Sharples 2014). They have been applied to the assessment of potential World Heritage sites in karst (Williams 2008) and provide guidance for State Party nominators.

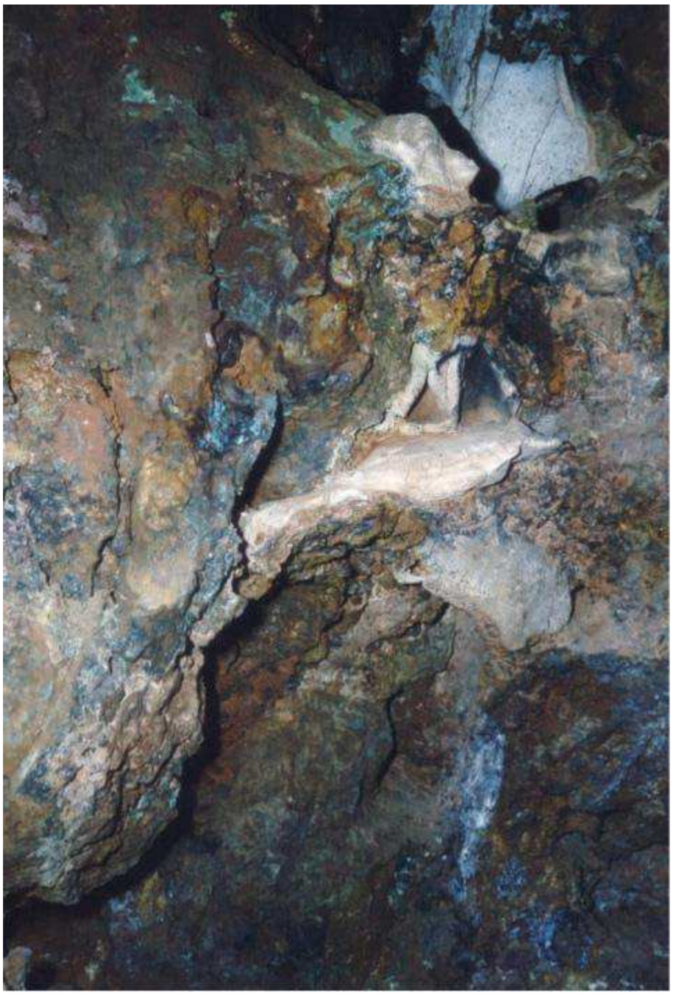

Figure 3. Copper sinter deposit associated with sediment infill in Tea Tree Cave, Chillagoe. Photo: David Gillieson.

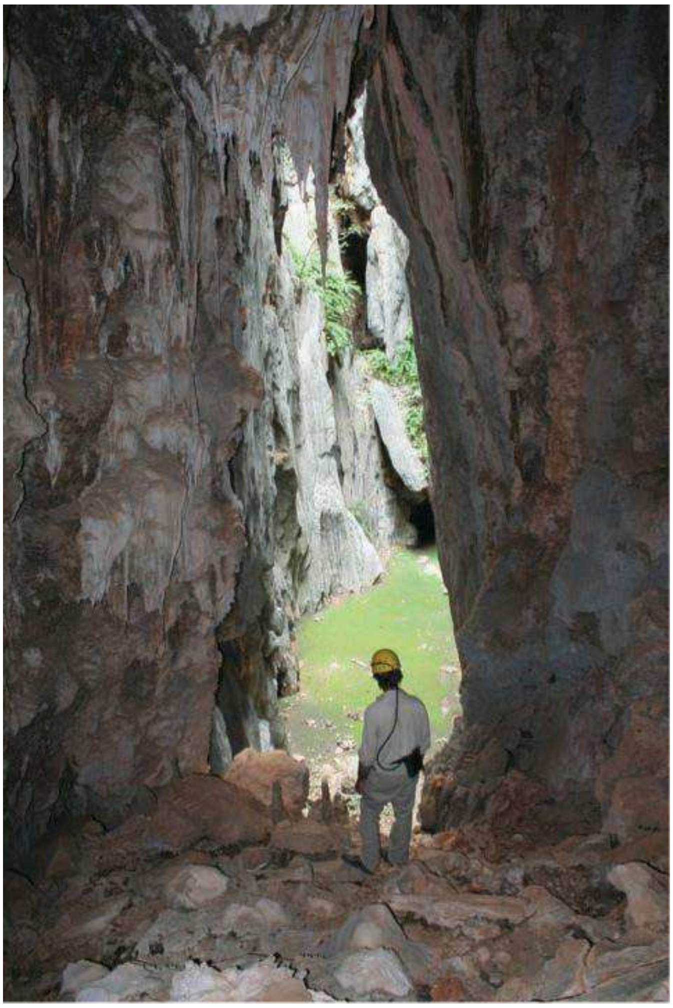

Figure 4. Solution corridor in Queenslander Cave, Chillagoe. Corridor intersections produce larger amphitheatre chambers which may contain ponds in the wet season. Photo: David Gillieson.

Geoheritage values – Chillagoe and Mitchell-Palmer karsts

The karst towers or bluffs at Chillagoe extend over a considerable distance in a series of sub-parallel blocks, and achieve heights of up to 65 m above the surrounding undulating terrain. Further north the karst towers at the Mitchell-Palmer area achieve greater heights (Fig. 2) and extend over a distance of 80 km between the Mitchell and Palmer rivers.

There is good evidence to suggest that the karst towers are least of Jurassic age (160 million years), as there is a demonstrated unconformity between the Chillagoe limestone and overlying Jurassic sandstones near Bellevue station. Blocks of Jurassic limestone also unconformably overlie the limestone at the top of Piano and Spring towers and also at the entrance of CH208 cave. Copper sinter deposits (Fig. 3) due to hydrothermal activity some 280 million years ago in the Permian (Nethery 2005) are also found in a few caves, and may provide a maximum age for the initiation of cave development.

Surrounding the Chillagoe towers and formed in the same limestone are low-angled pediments or ramps – inclined erosional surface covered with a thin layer of sediment. Some are narrow (20–30 m wide) and have a steep slope (around 20º). Others are gentler and several hundred metres wide with rock pavements, thin veneers of soil and limestone rubble. 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. Close to the major rivers the karsts are covered with river sediments at their margins and small swamp slots are present. In the higher and more extensive Mitchell-Palmer Karst, the towers are flanked by steeper bedrock ramps with skeletal soils and some scree (rocky debris). In all cases cave entrances are commonly found at the junction of the ramps or pediments and steeper slopes above.

Most of the towers of the Chillagoe and Mitchell-Palmer Karst have very well developed solution rills which drain the upper surfaces of the pinnacles and feed larger solution runnels. Within the solution rills are often low sub-horizontal ribs of limestone (solution ripples). There are extensive solution pans on the upper surfaces of the towers, along with deep clefts and solution corridors (Fig. 4). Solution along vertical joints and bedding planes within the limestone has produced the clefts; these range in size from a few tens of centimetres across to extensive corridors that may be 10 m wide and 30 m deep. A few of the larger towers contain amphitheatrelike depressions filled with large limestone blocks; these probably represent large collapsed cave passages.

Some towers have developed in coarse sugary marble (sugarstone), formed by contact metamorphism around the margins of the granites. The marble towers have a rounded, domed appearance with extensive exfoliation sheets; some of these may relate to spalling after grassfires. Solution rills, if present, are shallower and rounder than on limestone towers, and may be absent altogether. The subsoil weathering of the marble produces a micro-pitted surface, particularly evident in finegrained varieties; this contrasts with the smoother subsoil surfaces formed on un-metamorphosed limestone.

Speleothem (cave calcite) deposits are common in almost all caves, and may completely block passages. The most abundant form is cave coral, rough knobbly protrusions usually only a few centimetres long that cover large areas of cave walls, along with a form of moonmilk. Two types of stalactites are common within the caves, normal stalactites and "suckerpads". Suckerpads are large stalactites up to 1 m across and 8 m long that terminate not in a point but as a subhorizontal plane covered in small cave coral. The outside surface of suckerpads is rough and chalky, though they appear to be active during the wet season, when water can often be seen dripping from their flat terminations. Their origin is uncertain; the flat terminations do not represent an old floor or water level, as they occur at a variety of heights within the one passage, and some are even slightly inclined.

Cave floors are composed of a mix of fallen rock slabs and flat silt or clay; many caves also have deep guano deposits. False floors are often present 10–20 m above the present floor. The sediment remnants beneath the false floors are reddish breccias that may contain bone deposits. These bone breccias (Fig. 5) have yielded a probable Pleistocene fauna (1.8 million to 12,000 years old) including several extinct mammals (*Phascolomys* and

Figure 5. Cave breccia containing subfossil marsupial bones in a Chillagoe cave.
Photo: David Gillieson.

Palorchestes), and a Ziphodont crocodile. 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. On the walls of many cave entrances and daylight chambers oriented rock needles with algal associations (phytokarst) are well developed.

Biological heritage values

Inland dry rainforests on limestone have strong affinities with the humid rainforests of the northern wet tropics and the eastern Australian coast. This suggests an evolutionary link between humid and arid (inland) communities (Fensham, 1995). Many of the animals and plants of the dry rainforests are restricted or endemic to these communities, while others have Gondwanan affinities. Many of the animals and invertebrate groups including spiders, beetles and butterflies are dependent on the dry rainforests for food, shelter and breeding sites. Leaf litter from the dry rainforests is also a critical food source for cave invertebrate communities. Although dry rainforests are widespread in their extent, their patchiness and small size contribute to their uncommon status.

The Chillagoe-Mungana Karst dry rainforest associations demonstrate the principal characteristics of this class of natural environments. The dry rainforest of the Mitchell-Palmer Karst has close affinities, but the diversity of species is slightly higher in the Chillagoe-Mungana Karst. Dry rainforest communities are considered to be uncommon and threatened at the national level and seventy-five percent of their original extent has been cleared. In particular, Semi-deciduous Vine Thicket (Regional Ecosystem [RE] 9.11.8) and its associated plants is listed as Near Threatened under the Qld Nature Conservation Act (1992).

The Chillagoe-Mungana dry rainforests contain four nationally rare or vulnerable plant species (*Graptophyllum excelsum, Alectryon tropicus, Atalaya calcicola* and *Macropteranthes montana*), two endemic plant species (*Terminalia chillagoensis* and *Brachychiton chillagoensis*), and two limestone-dependent plant species, *Graptophyllum* sp. and *Flueggia* sp., which also occur in the Fanning River Karst near Townsville.

Dry rainforests between Rockhampton and Chillagoe show eight major floristic groupings and 16 sub-groupings, some currently restricted in distribution, and others spread over a large area occurring on a large number of landforms and soils. These groupings overlap, forming three major centres of biodiversity. They appear to be regional refugia for these nationally restricted communities. The northern refuge, centred in the Chillagoe/ Mount Garnet area, has nine floristic groupings, seven of which are endemic (Fensham 1995).

The dry rainforests are floristically distinct from, but closely related to the monsoon rainforests of Western Australia, the Northern Territory and Cape York Peninsula in far North Queensland. There is also a strong degree of floristic overlap with the littoral rainforests of the Queensland coast with 87% of the inland woody species also occurring within 1 km of the seaboard (Fensham 1995). The exact nature of the relationships between these vegetation types and the inland dry rainforests of North Queensland is not known, and the puzzle is further complicated by generic (rather than species) overlaps with the rainforests of the Wet Tropics region. These complicated biogeographical relationships, coupled with the patchiness of distribution and lack of specific environmental preferences, have spawned a series of fierce debates as to the origins and evolution of the dry rainforests (Fensham 1995).

The habitats of the Northern Quoll (*Dasyurus hallucatus*) and the Greater Large-eared Horseshoe Bat (*Rhinolophus robertsi*) are both listed as Endangered under the EPBC Act and are closely associated with limestone outcrops and caves. The caves of the Chillagoe-Mungana karst are also important as roosting and maternity sites for the Chillagoe Australian Swiftlet, *Aerodramus terraereginae chillagoensis*., and over 2,000 individuals have been recorded from here (Tarburton 1993). It is a poorly known bird suspected of being a nationally threatened sub-species, and also occurs in a few caves in the Mitchell-Palmer karst to the north.

The Chillagoe caves host 17 bat species including Bentwing Bats (*Miniopterus schreibersii* and *M. australis*), Common Sheathtail Bat (*Taphozous georgianus*), Horseshoe Bats (*Rhinolophus megaphyllus* and *R. philippinensis*), Leafnosed Bats (*Hipposideros ater* and *H. diadema*) and Eastern Cave Bat (*Vespadelus troughtoni*). At Mitchell-Palmer one cave contains a roosting site for the Ghost Bat (*Macroderma gigas*).

The invertebrate cave faunas of the Chillagoe and Mitchell-Palmer Karsts are not well known, but preliminary studies suggest the caves' faunas share common characteristics with the rainforest karsts across northern Australia. About 19 species of troglobites and two species of stygobites are known are known from the caves in this area (Howarth 1993). One of the more diverse invertebrate groups found in the caves of the Australian wet tropics are plant hoppers (*Homoptera*) of the fulgoroid families Cixiidae (especially the genus *Solonaima*) and Meenoplidae (especially the genus *Phaconeura*). North Queensland has the highest concentration of cave-adapted plant hoppers (*Fulgoroidea*) in the world (Hoch and Howarth 1989a,b). These are found in the caves of Chillagoe, but the number of species present has not been verified. Aquatic cave communities in these karsts have not been researched in detail, but of note is the endemic blind amphipod, *Chillagoe thea*. This amphipod colony in Tea Tree Cave has been the subject of water level monitoring and chemistry studies by the Queensland Department of Environment and Heritage Protection.

Evidence is increasing that a vast array of life forms exists underground in water-filled fractured limestone rock and caves (Culver and Pipan 2009). These invertebrate stygofauna are characterised by convergent morphological features including loss of eyes, pigmentation and elongation of appendages. From studies in Europe and America (Gillieson 1996), physiological and behavioural adaptations probably also occur, but knowledge of the basic biology and ecology is largely lacking. Initial work in Australia (Hamilton-Smith and Eberhard 2000) suggests that diversity is greatest in the tropical north. The Chillagoe and Mitchell-Palmer karsts have high potential for interesting research into the biogeography of tropical biological systems. The area is highly significant biologically but is poorly known in terms of described species or their ecology. Isolation of invertebrate populations in separate towers appears to have led to significant speciation but whether caves within towers represent isolated populations is completely unknown.

Comparative heritage analysis

The most obvious comparison is with the Limestone Ranges of the Kimberley in WA. The geologic context there is quite different, with Devonian reef limestones occurring in broad belts with original depositional structures still evident, for example at Windjana Gorge. The karst of the Limestone Ranges is also dissected by larger rivers such as the Lennard and Fitzroy, as well as smaller creeks and spring outflows such as at Brooking Gorge. The larger caves in the Kimberley are associated with major springs or antecedent stream capture eg. Tunnel Creek. Although there are some higher level caves, eg. Pigeon's Cave, these relate to former levels of the major rivers and there is no evidence of hydrothermal activity (though this is not impossible). Mimbi Cave is a very extensive floodwater maze cave with some phreatic features. In other areas of the tropics comparisons could be made with much smaller areas such as the Colless Creek karst (Lawn Hill), Broken River karst, Christmas Creek, Limestone Ridge and Mount Etna NP.

The Chillagoe karst demonstrates a greater diversity of karst landforms due to its structural complexity and lithological variation. In addition the Chillagoe karsts are isolated outcrops of limestone or marble, arising from surrounding pediment slopes developed in cherts and other sedimentary rocks. The caves of the Chillagoe area also exhibit greater variation, ranging from extensive maze caves formed by slowly moving groundwater, to rift systems developed along fault alignments and vertical rifts with decorated chambers at their base. While these karst towers are not as extensive or spectacular as those near Guilin in China, they are exceptional in Australia and are comparable with the mogotes of Cuba and Puerto Rico, as well as tower karsts in Madagascar. They are also far more accessible and thus have significant educational value.

A nomination for the Chillagoe and Mitchell-Palmer karst areas was submitted by the author in 2009 and a lengthy correspondence with the Department of Environment ensued. The proposed boundaries of the place were adjusted to avoid current mining leases, reducing the total area by around 50%. Additional information and photos were provided to the Australian Heritage Council.

The Australian Heritage Council has now assessed the Chillagoe Karst Region for potential National Heritage values (Department of the Environment 2015). The Council has identified that the Chillagoe Karst Region (including parts of the Mitchell-Palmer Karst Belt) met the National Heritage criteria for its outstanding karst limestone bluffs, towers and cave development. The specific criteria met were as follows:

> *"B (Rarity) Tower karst is an unusual landscape type in Australia, with the best examples found in the Chillagoe Karst Region. Tower karst are distinctive steep sided limestone outcrops, some in the Chillagoe Karst Region attain heights of over 100m.*
>
> *D (Principal characteristics of a class of place) The Chillagoe Karst Region contains the best examples of tropical limestone bluffs and towers in Australia, and is potentially significant at a global level with the closest comparisons being in Cuba and Madagascar. The cave systems include over 1,000 recorded and mapped caves, the largest extent of cave development in Australia.*
>
> *E (Aesthetics) The Chillagoe Karst Region is renowned for its spectacular limestone towers that are the best examples of their kind in Australia".*

The Council's assessment was made available for public review and comment until November 2015, and following this the assessment and comments are now with the Minister for the Environment for his final decision.

Ongoing conservation and management issues

Little is known about traditional Aboriginal burning practices in the Chillagoe area. It is likely that small patches were burnt seasonally to clean up country and provide a mosaic of regeneration favouring perennial plants and wildlife. Aboriginal burning was carefully controlled and timed to achieve these goals. Following the introduction of grazing by cattle, much larger areas were burnt in individual fires and the seasonality of burning changed (John Fred, QPWS, pers. comm.). Older residents assert that this has caused a change in composition of the grasslands to more annual species, and associated hydrological changes due to compaction and reduction in soil infiltration rates. Pastoral properties in the area currently favour early dry season burns (May to July), with fire exclusion in the dry season itself. Storm burns are then carried out at the onset of the wet season (November to December) to favour the growth of green pick (Crowley & Garnett 2000). This may also enhance the availability of grasses such as cockatoo grass (*Alloteropsis semialata*). Cockatoo Grass fills an important role in the tropical savannas of Australia, providing food for seed-eating birds and small mammals (Crowley 2008). It can be considered a "keystone" species for at least two animal species that rely on it to survive when other foods are unavailable, the Golden-shouldered Parrot (*Psephotus chrysopterygius*) and the Northern Bettong (*Bettongia tropica*). There is ongoing interaction between the pastoralists and the Parks Service, with a well-developed fire management system designed to provide a better prescription for fires for strategic purposes.

The dry vine thickets that cloak the limestone outcrops are vulnerable to fire (Fensham et al. 1994; Fensham 1995), and their margins may be degraded by fire spreading from adjoining grassland into areas where weed species have established. Under past intensive grazing regimes, fuel loads in grassland were kept low. The removal of grazing from many areas is creating a dense growth of native and introduced grasses, as well as some shrub encroachment. This promotes more intense fires which have the potential to burn onto the limestone and further reduce the total area of vine thicket. The edge of the burnt vine thicket is a key site for the invasion of Indian Couch (*Bothriochloa pertusa*), which will help carry fires further into the vine thicket vegetation.

In common with many other limestone area, weeds have been introduced throughout the European history of the area. There has been a long-term program in the Chillagoe area to reduce weed populations, with some success. The shrub chinee apple (*Ziziphus mauritiana*) was widespread in the area but has been brought under control following a vigorous eradication programme by QPWS. This has involved chemical control with Tordonax being used initially, then later Access, which is regarded as being very effective. The rubber vine *Cryptostegia grandiflora* has been widespread along watercourses and has invaded adjoining grasslands. It can be controlled by judicious use of fire and increased grassy fuel loads have assisted this. It is now reduced to isolated thickets in grassy landscapes. Invasive grass species such as grader grass (*Themeda quadrivalvis*), spread through disturbance, and have been reduced with fire exclusion in a five year trial at Royal Arch bluff. The tall weed *Hyptis suaveolens*, a problem throughout north Queensland and the NT, is controlled by spraying. Long term plans for weeds involve reduction in chemical spraying and strategic use of fire as a control measure.

Feral cats (*Felis catus*) have been recorded in many areas, and have significant impacts on bats and swiftlets within the caves. A trapping program near the Royal Arch tower to reduce numbers (Alanna Little, QPWS, pers. comm.) has been successful. A local decline in the numbers of the Northern Quoll may be due to competitive exclusion by cats. Feral pigs (*Sus scrofa*) are widespread and pose a problem throughout north Queensland. Trapping and shooting have been carried out opportunistically throughout the Chillagoe area. Feral pigs not only cause major ecosystem disturbance through uprooting and trampling of native vegetation, may act as disease vectors, and predate on frogs and other small vertebrates. Cane toads (*Rhinella* [*Bufo*] *marina*) are present in the area and guides eradicate them in developed caves whenever possible.

The region has a long history of mining and Chillagoe represented one of the largest metallurgical developments in Queensland before World War 1, with a focus on copper, lead, silver and gold (Fig. 6) (Kerr 1992). After the 1920s the profitability of operations in the district dwindled and had largely ceased by the end of World War 2. In the 1980s, and after exploration by a range of companies, Amoco Minerals identified potentially payable gold bearing ore near the former township of Mungana and in 1983 Mungana Mines Ltd was formed. Active mining operations commenced with the Red Dome Project in the mid-1980s, however this had largely ceased by 1997 apart from ongoing rehabilitation. In 2006 Kargara Ltd recommenced active operations in the Red Dome Project area with the development of the Mungana polymetallic underground mine. This has now closed, and a more recent 2012 proposal to re-open the Red Dome mine by Mungana Gold Ltd has fortunately been shelved.

Some small-scale quarrying of marble by family businesses is carried out in the area. There has been concern over the de-watering of small quarries in the vicinity of Tea Tree Cave at Chillagoe, which might lower the cave pools and cause local extinction of the stygofauna therein. Any surface discharge of water might eventually enter the cave, and the main ongoing concern would be hydrocarbon pollutants in the pumped water. We know very little about the detailed hydrology of the Chillagoe area, and dye tracing in the wet season might help elucidate the flow paths through the caves and groundwater to the springs.

The impacts of visitors upon the surface and sub-surface features of a karst environment are well known to cave and karst managers everywhere, as are the challenges of regulation of commercial and recreational usage of these resources (Watson et al. 1997; Gillieson 2011). There has been a fairly standard approach adopted at Chillagoe, where people may choose to partake in a commercial guided cave tour, or visit a free-entry nominated self-guided site or walking track without the requirement for further permitting. Persons seeking a caving experience beyond these limits need to apply for a special activity permit if they intend to cave within the National Park or adjacent areas. The restrictions imposed on such applicants are aimed at protection of the resource, safety of the participants and reduction of the liability of the landholder. Currently, all guided cave tours in developed caves are conducted by QPWS staff. In the near future, it is proposed that these same caves be made available for other commercial tour guides to use. Guidelines for these operators will presumably be underpinned by the same basic tenets as for recreational caving.

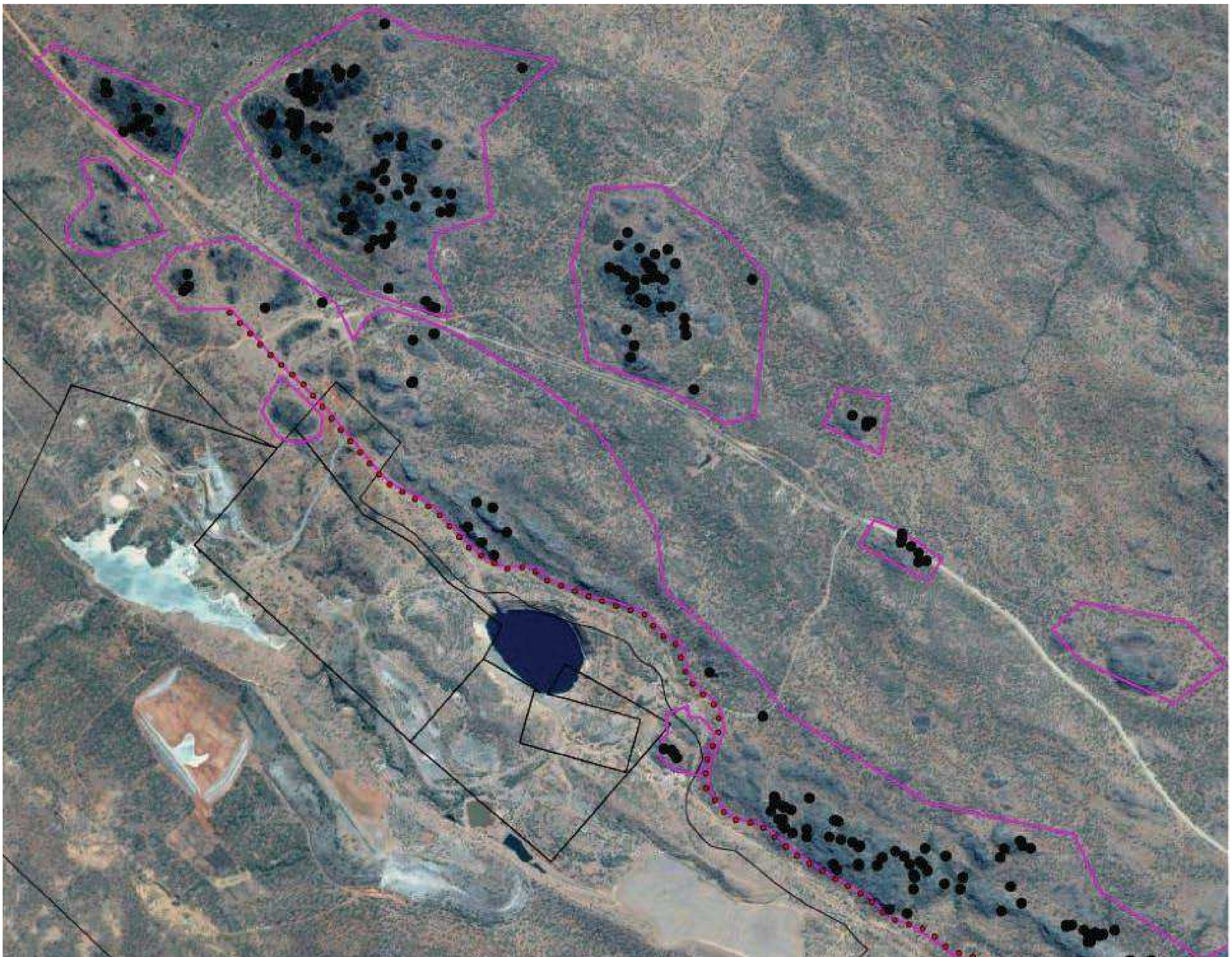

Figure 6. Limestone bluffs adjacent to former Red Dome Mine, Chillagoe.
Purple lines represent proposed National Heritage List boundary, black dots are cave entrances. Vector data from ERIN and Australian Speleological Federation; base map is an IKONOS satellite image dated 3 September 2010.

References

Chillagoe Caving Club. 1982. *Chillagoe Karst*. Chillagoe Caving Club: Cairns.

Crowley G. 2008. Cockatoo Grass *Alloteropsis semialata* as a keystone species in northern Australia. Northern Territory Naturalist 20: 58-63.

Crowley GM, Garnett ST. 2000. Changing fire management in the pastoral lands of Cape York Peninsula of northeast Australia, 1623–1996. *Australian Geographical Studies* 38: 10-26.

Culver DC, Pipan T. 2009. *The Biology of Caves and other Subterranean Habitats*. Oxford University Press: Oxford.

Department of the Environment. 2015. *Chillagoe Karst Region National Heritage assessment Department of the Environment: Canberra. http://www.environment.gov.au/heritage/places/national-heritage-list/chillagoe-karst-region-proposed-national-heritage-listing,* downloaded 20 November 2015.

Fensham RJ. 1995. Floristics and environmental relations of inland dry rainforest in north Queensland, Australia. *Journal of Biogeography* 22: 10-47.

Fensham RJ, Fairfax RJ, Cannell RJ. 1994. The invasion of *Lantana camara* L. in Forty Mile Scrub National Park, north Queensland. *Australian Journal of Ecology* 19: 297-305.

Gillieson, D. 1996. *Caves: Processes, Development and Management*. Chapter 8 Cave Ecology, pp. 203-236. Blackwell: Oxford.

Gillieson D. 2004. Chillagoe and Mitchell-Palmer Karsts, Australia. In *The Encyclopedia of Caves and Karst Science*, ed. J Gunn, pp. 215216. Taylor and Francis – Routledge: New York.

Gillieson D. 2011. Management of Caves. In *Karst and Cave Management*, ed. P Van Beynen, pp. 141-158. Springer: New York.

Grimes KG. 1995. *A Classification of Geological and Geomorphological Features*. Accompanying volume of a report prepared for the Australian Heritage Commission by the Standing Committee for Geological Heritage of the Geological Society of Australia Inc.

Hamilton-Smith E, Eberhard S. 2000. Conservation of cave communities in Australia. In *Subterranean Ecosystems*, eds. Wilkens H, Culver DC, Humphreys WF, pp. 647-664. Elsevier: Amsterdam.

Hoch H., Howarth FG. 1989a. Six new cavernicolous cixiid planthoppers in the genus Solonaima from Australia (Homoptera:Fulgoridea). *Systematic Entomology* 14: 377-402.

Hoch H., Howarth FG. 1989b. The evolution of cave-adapted cixiid planthoppers in volcanic and limestone caves in North Queensland, Australia (Homoptera:Fulgoroidea). *Mémoires de Biospéleologie* 16: 17-24.

Houshold I, Sharples C, Dixon G, Duhig N. 1997. Georegionalisation – A more systematic approach for the identification of places of geoconservation significance; In *Pattern and Process: Towards a Regional Approach to National Estate Assessment of Geodiversity*, ed. R Eberhard, pp. 65-84. Technical Series No. 2, Environment Australia and the Australian Heritage Commission Environment Australia: Canberra.

Howarth FG. 1993. High-stress subterranean habitats and evolutionary change in cave-inhabiting arthropods. *American Naturalist* 142: 65-77.

Kerr RS. 1992. *Chillagoe: Copper, Cattle and Caves: an Historical Guide*. JD. and RS. Kerr: St Lucia, Queensland.

Matthews PB. 1985. *Australian Karst Index.* Australian Speleological Federation: Melbourne.

Nethery J. 2005. New evidence and constraints on the age of the Chillagoe karst. In *Cave Management in Australasia 15. Proceedings of the 15th Australasian Conference on Cave and Karst Management, Chillagoe Caves and Undara Lava Tubes, North Queensland,* p. 10. Australasian Cave and Karst Management Association Inc: Carlton South, Victoria.

Sharples C. 2002. *Concepts and Principles of Geoconservation.* Tasmanian Parks & Wildlife Service: Hobart.

Sharples C. 2014. *A Thematic Gap Analysis of the Tasmanian Geoconservation Database: Glacial and Periglacial Landform Listings in the Tasmanian Wilderness World Heritage Area.* Resource Management and Conservation Division, Department of Primary Industries Parks Water and Environment, Hobart, Nature Conservation Series 14/4: Hobart.

Tarburton M. 1993. The diet of the White-rumped Swiftlet (*Aerodramus spodiopygius*) in Queensland's savannah. *Avocetta* 17: 125-129.

Watson J, Hamilton-Smith E, Gillieson D, Kiernan K. 1997. *Guidelines for Cave and Karst Protection*, World Conservation Union (IUCN): Gland, Switzerland.

White S, Wakelin−King G. 2014. Earth Sciences Comparative Matrix: a comparative method for geoheritage assessment. *Geographical Research* 52: 168-181.

Williams PW. 2008. *World Heritage Caves and Karst*. IUCN: Gland, Switzerland.