

Glossary of Terms

for Ruiniform and Karst-like features in Silicate Rocks

compiled by

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October 2009

Cover photograph is of part of the Limmen West stone city, NT. Showing pinnacles, tessellations and a case-hardened joint.

Photo KG080918.

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PREFACE

This glossary accompanies and provides illustrated definitions of the terms used in our report to the Commonwealth Department of the Environment, Water, Heritage and the Arts on the ruiniform and karst-like features of the sandstone, granite and laterite areas of North Australia (Grimes et al., 2009).

The purpose of the glossary is twofold. Firstly, for the staff of the Department, we have provided definitions of technical terms in the report – this includes some additional basic terms (such as dip and strike) needed to understand the definitions of the more complex terms. Secondly, for other geomorphologists, we have had to define new terms such as those used for the components of *stone cities* and also to indicate our usage of some existing terms (e.g. *tafoni*) which have had a varied and sometimes conflicting application in the literature.

For additional discussions of nomenclature, including the unresolved distinctions between *karst*, *parakarst* and *pseudokarst*, see pages 7-8 in the main report and citations in the bibliography to this glossary.

Photos are referenced by their file names. **Bold** print indicates a photo that is reproduced within the glossary (see index, page 27). Other photos referenced here have been supplied to the Department on the DVD-ROM accompanying the main report.

Words in *italics* are defined elsewhere in the glossary.

Abbreviations:

AKA = Also Known As ...
The following are used for size or in ratios:
L=Length, W=Width, H=Height, D=Depth. S=Spacing (wavelength)

Acknowledgments

Two figures were taken (with minor changes) from publications by Cochrane et al., 1991 and Martini, 2004.

Nick White is thanked for the use of his photo of a "tor". All other photos are by the authors, who retain copyright – the first two letters of the file name are the initials of the author.

Satellite images are from Google Earth. The air photo on page 16 is © NT Government.

Alcove Arête

Illustrated Glossary of Terms for Ruiniform and Karst-like features in Silicate Rocks

Ken Grimes, Robert Wray, Andy Spate & Ian Houshold

Alcove: Used here for a *cavernous weathering* hollow in a cliff face that is a few metres high and wide and a metre or so deep, and which may contain smaller *tafoni* and *pseudo-karren* on its rear wall. Best examples are at Mt. Moffatt (photo **KG084357**).

Alcove: with smaller tafoni. KG084357 Mt. Moffatt, Qld.



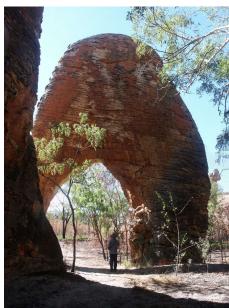
Amphitheatre: A large semi-circular or enclosed embayment cut behind a cliff line (Young et al, 2009; Figure 2).

Arch: We make a distinction between an *Arch* which is formed by weathering etc as against a *Bridge* which is formed by fluvial (or marine) erosion and bridges over a watercourse (or remnant stream cave). However, many people use either term indiscriminately. Where uncertain (e.g. a distant view from an aircraft) we use *Arch*. Photos KG080538a, KG080837P, KG084392. In *stone cities*, some "arches" bridge across a city street (e.g. KG082997).

Arenisation: A process of interacting chemical and physical processes that can lead to development of ruiniform and karst-like features in quartzose rocks. It entails slow chemical dissolution along crystal boundaries to free grains and leave the rock less competent and more susceptible to physical erosion (Figure 1, Martini, 2004). Sand grains can then be easily removed by flowing water and *piping*. The weathering process is commonly concentrated along *joints*, and the preferential erosion of the arenised grains from those zones produces *ruiniform* terrain.

Arête: A narrow, sharp-crested, steep-walled, ridge of rock. Examples occur at Limmen South where

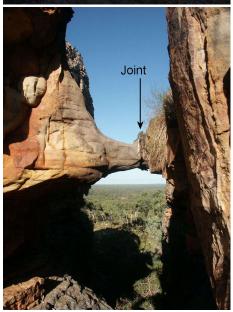
Arch: KG080837P Limmen W, NT.



Bridge across a stone city lane. Note the joint which controlled the initial development of the lane.

Width of lane is about 2-3 m.

KG082997 Bunju, NT.



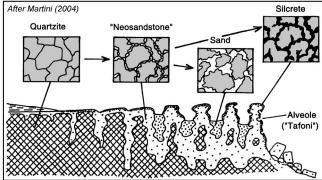


Figure 1: Arenisation: The process of loosening of sandstone grains to produce a readily-eroded material. Note the selective weathering along joints to form *grikes* and *pinnacles*.

Avenue Boulder cave



Barrier Wall across a street in a stone city. Stream flow goes through a narrow *fissure* (arrowed). KG080779, Limmen South, NT.



Beehive pinnacles: KG082678, Purnululu, WA.

a *grikefield* has a single set of close-spaced grikes separating equally narrow sharp ridges or walls – the arêtes.

Avenue: (new term) see stone city components (avenue).

A broad street in a stone city. AKA box valley (page 3).

Barrier Wall: (new term) See *stone city components* (barrier wall) for a specialised use of this term for a wall blocking a city street. Stream flow may penetrate it via a small cave or a narrow fissure – possibly creating a bridge. (Photo **KG080779**)

Beehive: A distinctive type of *pinnacle* or tower – bell-shaped with rounded top, steep-sloping sides and a base that may be flared or form an abrupt angle with the pediment (see figure 7 on page13, photos KG081182, 2661, 2678). The surface is sculptured by etched bedding or *tessellations*.

Blind Valley: A valley that ends abruptly with the water flow being lost underground through a *streamsink*. The termination may be a cliff or section of reversed slope and the abandoned valley downstream is called a *dry valley*. A **semi-blind valley** occurs where the streamsink is unable to take

large flood flows so the downstream valley still flows on occasions. See Figure 2 and Figure 13, page 22.

Block: See stone city components (block).

In general usage this refers to a very large and angular chunk of solid rock, bigger than a boulder.

However, in the context of a *stone city* (q.v.) a city block is a large (generally rectangular) upstanding mass separated by the streets. (Figure 9, page 18, photos **KG080565a. 0566**; **RW083223**, pages 14, 18, 17).

Block gliding: Lateral and slightly downward movement of large blocks under gravity, commonly along a lubricated bed. cf. *cambering*.

Bogaz: see box valley, avenue & street.

Bollard: a squat block of sandstone rising from a cave floor – either the base of a broken *pillar* or a remnant of a partition between adjacent passages. cf. *pendant*, which hangs from the ceiling.

Bornhardt: A domed steep-sided hill or *tower*, structurally controlled and formed by differential erosion (possibly stripping of a deep weathered mantle). Photo KG081467. The term is mainly used for granite domes, but has been applied to sandstone domes (e.g. Ayres Rock, Uluru).

Boulder cave: A complex three-dimensional array of cavities left between boulders — essentially a large inter-granular porosity in which the grains are boulders rather than sand-sized. See photo KG083422J. Weathering of granites, and some other massive well-jointed rocks, leaves rounded corestones surrounded by soft weathered material which can be washed out to leave spaces that comprise the cave. There are two types: in-valley boulder caves form along a valley, and are generally a result of infilling by talus boulders, with the fine material removed by the valley stream. In-mountain boulder caves (as at Black Mountain, Qld) form an in situ skin, several boulders thick, across a mountain, by removal of the weathered material.

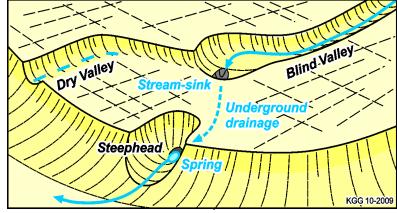


Figure 2: Blind Valley: a result of underground *stream capture*. The abandoned section is a *dry valley*. Also shown is a **steephead** which has the shape of an **amphitheatre**.

Box Valley Cave



Boulder Cave: formed between granite corestones. KG083422J, Metal Hills, Chillagoe, Qld.



Box Valleys: 30-100m wide *avenues* within a *stone city*. Satellite image, Limmen South, NT.

Box Valley: (AKA corridor, bogaz, *avenue*) A moreor-less straight, narrow valley, flat floored and steep walled (joint or fault controlled). Larger than a *giant grike* - say W >10m. The best examples seen were in one part of Limmen South, where they contrasted with the narrower city *streets* (see satellite photo above).

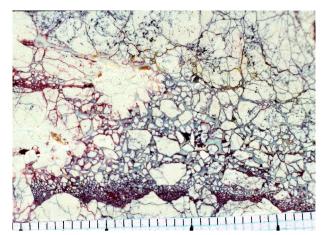
Breccia: A body of broken rock. It may be broken in situ (as in many *laterite karsts*, photo **KGS860437**; and see *crackle breccia*), or transported a short distance (typically as subsidence within a cave). Fault breccias are fractured by movement along the *fault* line.

Bridge: See *Arch* – use *bridge* where it crosses a watercourse (or collapsed stream cave), *arch* otherwise. Photo **KG082997** (page 1).

Butte: A small (narrow) *mesa*. H>W.

Cambering: the opening up of joint fissures (*gulls*) behind a cliff by outward and down-slope movement of blocks. AKA *block glding*.

Capture: See stream capture.



Breccia: Downward-fining breccia in a *laterite* profile (scale in mm). KGS830437, Donors Plateau, Qld.



Case hardening (type 1) of a surface (a prior cave wall), with *cavernous weathering* eroding behind it. KG083820a, Cobbold Creek, Qld.

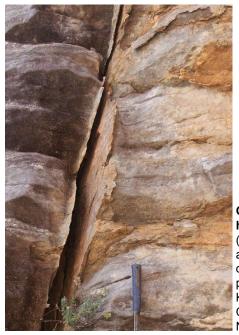
Case hardening: Cementation of a surface zone of a rock, by various processes and various materials (Young et al., 2009, p.150, Dorn, 2004). It occurs in several settings:

- 1: thin (1-3cm) sharply terminated cemented zone on exposed surfaces (photo **KG083820**, RW088066) often associated with cycles of wetting and drying of the rock surface;
- 2: thin (1-10cm), sharp, cemented zones on both faces of an open *joint* (photo KG080233, **KG080424** next page). In places, one side of a case-hardened joint appears to have been removed during the expansion of a stone city street;
- 3: less commonly, a thicker (1-2m) zone with a more diffuse boundary adjacent to a *joint* (photo KG084268a, KG084263P (next page); and see also *cemented wall*).

Case hardening can be a precursor to the formation of *cavernous weathering, tafoni* etc.

Cave: We distinguish between true **caves** that are human enterable, i.e. W>0.3m and penetrate deeper than the

Cavernous weathering Chemical deposits



Case hardening (type 2) along an open *joint* plane. KG080424, Caranbirinni, NT

entrance width (W<L), and rock shelters (W>L) and smaller (W < 0.3m) pipes (vertical & straight) and tubes (all directions). See also tubelet (W<=2cm). Partly-roofed grikes and unroofed passages are also excluded unless the roofed section is longer than the width (W<L).

Cavernous Weathering: Chemical and mechanical weathering on a cliff face, in which grains and flakes are loosened so as to enlarge hollows and recesses, a process also known as *granular weathering*. It is frequently, but not always, associated with the breaching of a *case-hardened* shell on the surface of a cliff. Photos: KG083326, KG083819. AKA *tafoni*, *alveoli*, *honeycomb weathering*, etc, and note there is considerable variation and overlap in usage of those terms, and the process is certainly polygenetic.

Here we use *cavernous weathering* as a broad term for the process and *tafoni* for individual hollows (all sizes) and *honeycomb weathering* for patterns of close-spaced small tafoni (Turkington, 2004).



Cavernous weathering: With case-hardened surfaces. KG083819, Cobbold Creek, Qld.

Cement: A chemical precipitate between the grains of a sandstone that binds it into a hard rock.

Cemented Wall: (new term) A wall of cemented rock following a central vertical *joint*. A result of diffusion of saturated waters out of the joint into the porous sandstone to *cement* it, followed by erosion of uncemented rock further out to leave an upstanding wall. See also *case hardening (type 3)*, Examples were seen in sandstone at Salvator Rosa (photo KG084263P, KG084268a) and Mt. Moffatt, and also in *laterite karst* at White Mountains (photo KG083287).

Cenote: A steep-sided collapse *doline* that contains a water-table lake. **Photo KG081248**.

Chemical deposits: Mineral deposits formed by precipitation of dissolved solids as a result of evaporation or various chemical reactions. They may form distinctively shaped *speleothems* or just smooth or lumpy coatings (Photos KG080378, 0397).

Cemented Wall: Broad (1 m wide) cementation beside a joint plane. KG084263P, The Wall, Salvator Rosa, Qld.





Cenote: A 260 m wide, water-filled, collapse *doline* in sandstone. Aerial view. KG081248, Bath Range, NT.

City Block Deep Weathering



Clints & Grikes: Slabs of rock (clints) within a grid of eroded joints (grikes). KG084939. Currarong, NSW.

Chemical Weathering: See weathering.

City Block: See *stone city (block)*. (Photo **RW083223**, page 17)

Clint: the tabular rock areas left between the crisscrossing *grikes* of a grikefield. May be flat and smooth or dissected by *karren* (in limestone). Photo **KG0834939**.

Conduit: a general hydrological term for *cave* tunnels, or smaller *tubes* or even *tubelets* which carry water flow, or have done so in the past. Photo **KG080089**. p. 17.



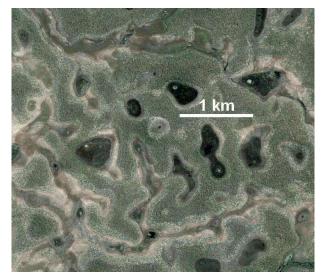
Silica **coralloid** *speleothems* in a sandstone cave. IH08072008 33, Kakadu, NT: Scale in cm.



Crackle Breccia: KGC010511, Wombeyan, NSW.



Cutters: Two soil-filled joint fissures in *deep-weathered* sandstone, KGS890128, Newlands mine, Qld.



Dambos and **Pans** on a lateritised old land surface, Cape York Peninsula, Qld (Satellite image)

Coralloid: See *speleothem*. Lumpy *chemical deposits* formed mainly by evaporation of thin films of water. AKA "popcorn", "cave-coral". Photo **IH8072008_33**.

Crackle Breccia: A type of solutional *breccia* in which the broken fragments have only moved or rotated a small amount and one can match edges or trace bedding lines through the mass (photo KGS860511).

Cutter: A soil-filled *grike*. Photo KGS890128.

Dambo: An unchannelled, flat-floored, low-order drainage line found in *laterite* plains. Commonly associated with laterite *pans* (q.v.). See image above

Deep Weathering: In tropical and sub-tropical regions, intensive weathering over a long period of time forms distinctive deep weathering profiles (Thomas, 1994). The rock is strongly weathered, and its original character can be totally obliterated. Photo KG088054P, KGS790512 (next page) The processes involve chemical weathering of all types, including solution, and can form a variety of karst-like landforms known as laterite karst.

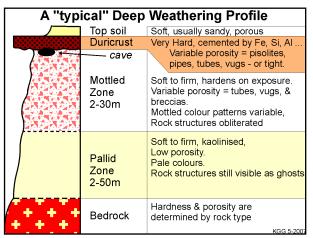


Figure 3: The typical components of a deep weathering profile – but note that there is considerable variation.



Deep Weathering Profile: A dark red laterite layer overlies a mottled zone. KGS790512, Anakie, Qld.

Deep Weathering Profile (DWP): A DWP can exceed 100m depth, but is typically 20-40m (figure 3, Photo KGS790512). It has a sandy top soil over a hard duricrust (ferricrete, silcrete), and below that may be a mottled zone and a pallid zone (AKA saprolite) above weathered rock in which the original structures are still partly preserved. But there is a lot of variation between and within profiles. Laterite is an alternative name for an iron-rich DWP. Secondary (karstic) porosity is most common in the mottled zone and within the duricrust, but again there is much variation.

Dip and Strike: Dip is the angle of slope of a bed. Strike is the direction of a horizontal line on the bed's surface (Figure 4).

Dip surface: a smooth sloping surface which follows a dipping bed (photo **IH28062008_75P** and Figure 4).

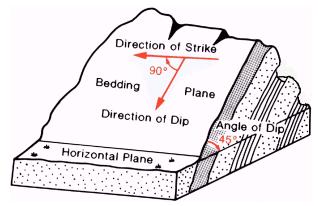


Figure 4: Dip & Strike (After Cochrane et al. 1991)



Dip surface: eroded surface of a resistant dipping bed. IH28062008 75P, Limmen, NT



Doline: Formed by collapse into a cave in the orange band. AS.Roper202, Bunju, NT.

The surface may be bare rock or soil covered. Commonly indicates erosion of a softer bed from above a harder bed. cf. *slickrock* surface.

Doline: AKA "sinkhole". A closed depression resulting from underground removal of material. See Figure 5 for the three main types. **Solution dolines** form from in situ solution of the surface rock. **Collapse dolines** result from the roof collapse of a large cavity and may

Doline Giant Grike

Figure 5: The three main types of doline or sinkhole.

have steep walls (Photo **AS.Roper202**, RW083814; see also *cenote* for a water-filled version). **Subsidence dolines** involve downward movement of softer material (e.g. soil). Broad but shallow subsidence dolines in *laterite karst* areas are called *pans* (photo **RW083632**, p.11, and see satellite image on page 5.

Dry valley: See also *blind valley*. The abandoned section of a valley left after underground *stream capture*.

Duricrust: The indurated part of a *deep weathering profile* (Figure 3). Photo **KGS720219**. Different types are named according to the dominant cementing material: **Ferricrete** (Fe), **Silcrete** (Si), **Alcrete** (or **bauxite**, Al). *Laterite karst* caves can form in the soft material beneath a hard duricrust.



Duricrust: A silcrete duricrust formed beneath an *old land surface* has been eroded to leave a group of *mesas*. KGS720219. Winton-Boulia road, Qld.



Epikarst surface: A *laterite karst* example. A detrital laterite soil overlies an irregular epikarst surface with grikes (*cutters*) and pinnacles. KG088054P. Excavation in city of Darwin, NT.

DWP: Short for *Deep Weathering Profile*.

Elephant Hide: A type of rectangular *tessellated* surface (q.v.) with etched bedding and vertical cracks. (Photo KG084542, KG084573, page 21)

Epikarst: In limestone karst, the name for the contact between the eroded upper surface of the limestone and the overlying soil (which may have been partly stripped). This is where a large part of the solutional denudation occurs. The epikarst surface is commonly deeply dissected by *grikes*, *cutters* and other subsoil *karren*. In the report we apply the term to similar surfaces in *laterite karst* (photo **KG088054P** and see Figure 6, page 10).

Exfoliation: see sheeting.

Fault: An extensive fracture plane along which one side has moved against the other (cf. *joint*).

Ferricrete: A type of ferruginous *duricrust* (q.v.). See also *laterite*. Photo **KGS830304**.

Fissure: has several meanings:

- 1: A cave passage that is elongated vertically (W<<H), usually along a joint (photo KG081823Px).
- 2: An open surface crack that is much deeper than wide (W<<D<<L), i.e. a deep *grike*, photo **KG080779** (page 2), KG083826Pb. cf *Gull*.

Flared surface: Where the base of a cliff or pinnacle curves outwards rather than having a sharp angle with the adjoining *pediment* (photo **KG080488P**, page 8).

Giant Grike: A large *grike*, Wider and deeper than usual, one can walk along the bottom (Photo **AS.Kak9070**, **RW084742**, both on next page).



Ferricrete: KGS830304, Tobeys Waterhole, Qld.

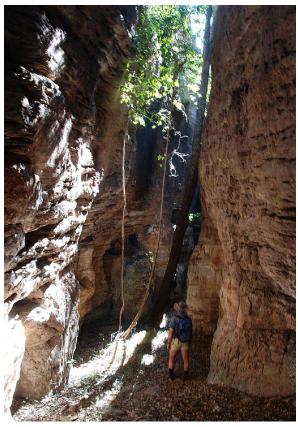
Giant Grikefield Gruss

Giant Grikefield: A composite landform comprising a pattern of *giant grikes* separating broad blocks (photo **AS.Kak9070**, RW083359). Grades to a *stone city* when the width of the grikes becomes comparable with that of the blocks (Wg:Wb > 0.5, see figure 8).

Granite: We use this as a general term for all coarse grained intrusive acid igneous rocks – i.e. rocks intruded in a molten state and cooled slowly beneath the ground so as to form large crystals that are visible



Flared surface: at base of a pinnacle. KG080488Pj, Abner Range, NT.



Giant Grike: A large grike. RW084742. Kakadu, NT.

in a hand specimen. The compositions vary (and there is a host of special names, which need not concern us here) but are dominantly quartz and feldspar.

Granite cave: See boulder cave.

Granular weathering: AKA exsudation, salt weathering. The granular disintegration of a rock surface by inter-granular solution and possibly crystal wedging associated with capillary water.

Grike: a solutionally enlarged *joint*, typically deeper than wide (photo IH28062008_42, **KG084939**, page 5, RW083220P). May be open or soil filled (*cutter*). Grades to *giant grike*. See also *grikefield* and *clint*.

Grikefield: A composite landform comprising a pattern of parallel or cross-cutting *grikes* separating *clints*. A type of *pavement*. Photo **KG080573** (on page 12), **RW083919**.

Gruss: An ill-sorted sand-clay residue formed by the weathering of *granite*. It is found more-or-less where it formed, with little transportation.



Giant Grikefield: Aerial view. AS.Kak9070, Kakadu, NT



Grikefield: The vegetated lines are soil-filled grikes. RW083919, Bunju, NT. Aerial view.

Gull Karst landforms



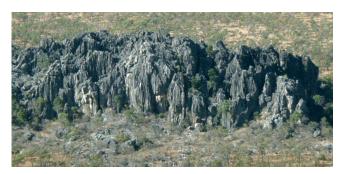
Honeycomb weathering: A coastal example from NSW. KG085077. (10 cm scale)



Joints: Three sets at right-angles form a blocky outcrop. KGC960620, Ormiston Gorge, NT.

Gull: An open (or partly roofed) *fissure* behind, and parallel to, a cliff. A result of *cambering* and massmovement of large blocks.

Half-pillar: See Pillar.



Large **Karren** grooves and pinnacles on limestone towers. KGS730528, Chillagoe, Qld. (Aerial view)



Kamenitza: A large solution pan in sandstone. KG081402P. Kakadu, NT.

Honeycomb weathering: Used in our report for regular patterns of close-spaced small (<10cm) *tafoni* (photo KG082337, 3611, KG085077). See *cavernous weathering* and Turkington (2004) for a discussion of the varied uses of these terms.

Joint: A planar crack without displacement (cf. *fault*). Usually found in sets forming a grid pattern. See photos **KGC960620**, **KG080424** on page 4.

Kamenitza: AKA "solution pan". A type of *karren* comprising a shallow flat-floored steep-sided hollow on a rock surface (photo **KG081402P**, 1408). The edges may be undercut. Thought to be formed by solution in which the floor is protected by a thin film of insoluble material so that the weathering is directed mainly at the edges.

Karren: A general term for small-scale solutional sculpturing. A broad variety of named types occur on limestone surfaces. Types on sandstone & granite tend to be restricted to *kamenitza* (solution pans), *grikes* and a variety of *runnels* (small stream channels), but it is not always easy to decide if the process forming a runnel is solution or stream erosion. cf. *Pseudo-karren* for linear sculpturing similar to karren, but not formed by solution. Photo KGS730528.

Karst: A distinctive set of landforms (see *karst landform*) produced primarily by solution (see *karst process*) of soluble rocks, in particular the carbonates (limestone & dolomite). See discussion in the Terminology section of the main report. c.f. *parakarst* and *pseudokarst*

Karst Hydrological Zones: See Figure 6 (next page)

Karst Landforms: A distinctive set of landforms and features: (a) on the surface: various types of closed depressions (including dolines), towers and pinnacles, streamsinks, springs, and karren (small-scale sculpturing), and a general lack of integrated surface drainage; and (b) below the surface: caves and an underground drainage through conduits.

Karst hydrology Mesa

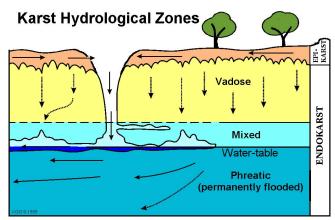


Figure 6: The hydrological zones - *Epikarst* (soil zone), *Vadose* (partly air-filled) & *Phreatic* (saturated with water). The mixed zone is one of fluctuating water-table. Arrows show water flow.



Karst Window: This flat-floored **doline** has a stream channel running across its floor. AS.Roper156, Bunju.

Karst processes: Solution is dominant or at least critical at some stage. However, other processes can contribute and even dominate – this is particularly so with the silicate *parakarsts*.

Karst Window: A *doline* or other closed depression that exposes an underground stream flowing across its floor. Photo **AS.Roper156**.

Labile: A term for the chemically unstable grains in a *sandstone* (or other rock), i.e. the feldspars and other minerals and lithic (rock) fragments as against chemically-resistant quartz. A quartz sandstone has less than 10% labile grains, a sublabile sandstone has 10-25% and a labile sandstone has >25% labiles (Crook, 1960).

Labyrinth karst: A karst term coined by Brook & Ford (1978) as a broad landform term for both *giant grikefields* and *stone cities* and possibly also *stone forests*. See also *Ruiniform* which is our preferred general term (Grimes et al., 2009).

Laterite: A type of iron-rich *deep weathering profile* (q.v.). It can host *laterite karst* landforms.

Laterite Karst: *Karst-like landforms* which form on *deep weathering profiles*. They form by a combination of solution, chemical weathering and other physical processes. See discussion in the main report and Grimes & Spate (2008).

Laterite Pinnacles differ from those on sandstone by being the result of focussed cementation, commonly around a solution pipe. Photo **KGS780512**.

Lost City: Popular term for *stone city* (q.v.). We prefer the latter as being more precise.

Lunette: A crescentic ridge of sand or finer material found on the lee side of an intermittent lake. Formed by a combination of wind and wave action.

Maze cave: A cave system composed of criss-crossing passages, in a rectangular or irregular grid.

Mesa: A flat-topped hill with steep sides, larger than a butte (W>H) but smaller than a plateau (photo KGS720219). The flat top is usually a distinctively resistant horizontal bed; e.g. sandstone, basalt or duricrust; or may be part of an old land surface.



Laterite Karst Pinnacles form by focussed cementation. KGS780512, White Mtns, Qld.

Microkarren Pendant



Mesas & Old Land Surface: Flat-topped hills. The summits mark an *old land surface* preserved because of its hard *duricrust*. KGS720219. Winton-Boulia road, Qld.

Microkarren: A very fine form of *karren* in which the grooves and pits are only 1-2mm wide.

Obsequent mountain: A mountain which was formerly the infilled floor of a graben (down-faulted trough) but which was left standing as erosion lowered the weak rock areas on either side, e.g. Ngarrabullgan (Mt Mulligan).

Old Land Surface: A recognisable remnant of an old erosional or depositional surface, unrelated to the present topography (which is typically eroding into it or burying it under sediment). Recognisable examples are plateau surfaces, mesas (photo KGS720219 above), bevelled ridge-tops, summit conformities and paleodrainage lines. Old land surfaces are often distinguished by laterites and deep weathering profiles and the duricrusts associated with these help to preserve the old surface from erosion.

Pagoda: A type of *pinnacle* which has a stepped profile due to notching and undercutting of horizontal beds (photo KG081796 & see figure 7, page 13)

Paleodrainage: A drainage line formed in the past and not related to or only weakly integrated with, the present drainage. Typically associated with *old land surfaces* or with *stream capture*. A good example at Cobbold Creek and a smaller one at Abner Range.

Pan: In this report, a broad but shallow hollow or *doline* typical of many *laterite karst* areas. They may have flat or gently basinal floors and usually a distinctive vegetation resulting from seasonal inundation (photo RW083632 and see also satellite image with *Dambo*, page 5). The term is also used by geomorphologists for shallow hollows formed by other processes in non-laterite areas, and some laterite karst pans have been modified by other processes such as wind erosion. "Pan" is also sometimes used as a short version of *solution pan* – a much smaller hollow.

Parakarst: Karst landforms produced dominantly by solution of non-carbonate rocks, or if not dominant where solution of those rocks is critical to the formation of the features (Grimes, 1997, and see also karst and pseudokarst). In many parakarsts solution (e.g. arenisation) is an important early stage of preparation, but the visible features have been eroded later by other, physical, processes, e.g. piping.





Pan: One of many shallow hollows on the lateritic coastal plain, western Gulf of Carpentaria, NT. RW083632.

Pavement: A karst term for a bare surface cut by karren (grikes & clints, or runnels). For our purposes used for any flat or gently sloping rock surface, with or without grikes & clints, and possibly with scattered pinnacles (e.g. photo KG080573, next page). cf. grikefield. Low level pavements correspond to pediments, but sandstone pavements also occur on plateau tops (photo KG080565, p.15). Steeper smooth rock surfaces are slickrock surfaces or dip-slopes.

Pediment: A smooth horizontal or gently sloping surface. Generally abutting the adjoining hills or pinnacles at a sharp break in slope (the *piedmont angle*, KG080522, 0568, **0573** next page). May be bare rock or thin soil. Results from erosion cutting back into the rock face. See also *pavement*, which is an overlapping term but has a broader usage.

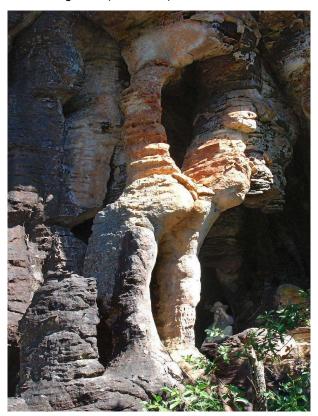
Pedimentation: This is the process of backward erosion of the foot of a hill-slope to leave a flat *pediment* and a steep retreating face.

Pendant: (or roof pendant) A block or blade of bedrock hanging from the ceiling of a cave – either the top of

Phreatic Zone Pipe



Pavement & Pediment: This sandstone pavement with *grikes* is also a *pediment*. Note the sharp break of slope (*piedmont angle*) against both the tall pinnacles in background and the squat ones to the left. KG080573. Abner Range, NT. (aerial view).



Pillar: Two levels of pillars in a cave entrance. RW084570bx, Kakadu, NT

a broken *pillar* or the remains of a partition between adjacent passages. cf. *bollard*, which sits on the floor. Photo **KG081820a**.

Phreatic Zone: In hydrology, the phreatic zone is the aquifer beneath the watertable, where all porosity is water-filled (cf. *vadose zone*). See figure 6, page 10.

Phreatic sculpture: in caves this refers to the rounded, hollowed, cuspate and spongy surfaces that distinguish



Pendant: A hanging remnant of a narrow cave wall. KG081820a, Kakadu, NT.

cave walls formed by solution within the phreatic zone. However, similar surfaces can form in other ways, in particular by *cavernous weathering* of sandstone, so caution is needed in interpreting such forms.

Physical Weathering: See Weathering.

Piedmont Angle: A sharp break in slope between a steep hillside and the *pediment* at its base. Photo **KG080573**.

Pillar: (new term / special usage). Pillars and half-pillars are vertical columns, commonly with fine *pseudo-karren* sculpturing, attached to the rock above and below. The back of a *half-pillar* is still attached to the rock – it is not free-standing like a true pillar. (photo KG082028). They occur in and beside cave entrances and at the base of some pinnacles (photo IH07072008_36, RW084570bx, KG081729P). They are commonly confined to a specific susceptible bed and possibly result from localised cementation by focused water flow (Aubrecht et al., 2008).

Pinnacle: (special usage in our report). A discrete, high but narrow, column or cone of solid rock (Photo **KG080912P**). A pile of separate boulders or blocks we call a *Tor*. Large pinnacles grade to *Towers* (photo KG084349 is an example near the size boundary). See *Stone Forest* for a group term for a field of close-spaced pinnacles. We use adjectives to describe the different forms (see figure 7): *beehive* (q.v.), capped (KG080687), conical, bell-shaped, *pagoda* (q.v.), waisted (KG080772), etc. Note that *laterite karst pinnacles* form differently to those on sandstone.

Pipe: For the report we restrict "pipe" to vertical *solution pipes* (q.v.), i.e. small (W<1 m) straight vertical cylinders that result from focussed vertical water flow, and we use *tube* as the broader term for small pipes in all directions (or branching etc). Thus, pipes are a subset of tubes. Photos **KG083063**, **3071**.

Piping Pseudo-karren

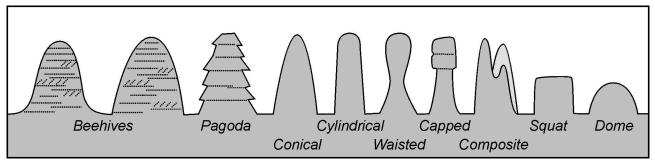


Figure 7: Types of Pinnacles.



Pinnacles: an assortment of types. KG080912P, Limmen West, NT.

Piping: A process of underground erosion in which solid particles are removed by water flowing through linear *conduits* (*pipes* or *tubes*). Some authors restrict it to the movement of clay particles, but we use a broader definition that also includes silt and sand-sized material. AKA suffosion.

Platea: A term used by Jennings (1983) for an open space within a *stone city*. But we prefer *Plaza* – see below and under *stone city components (plaza)*



Pipes: Two vertical pipes in a *laterite karst*; *breccia*-filled on left and open on right. KG083063 & KG083071. Sturt Plateau, NT. (10 cm scale)

Plaza: (new term) See *Stone city components (plaza)*. An open space of *pavement* replacing one or more blocks within a *stone city* – photo **KG081188**, and **0566** page 18.

Polje: A large flat-floored closed depression.

Polygonal walls: Low polygons found on laterite *deep* weathering profiles. The walls are generally up to 30 cm high and 20-50 cm wide with hollow cores from 0.5 to several metres across (photo KGS841404 next page. We interpret them as cemented areas between wide, but closely-spaced, solution pipes.

Pseudo-karren: A new term for the vertically elongate grooves and ridges found on vertical sandstone faces and *pillars* (especially close to the ground-level or in



Plaza within a giant grikefield. KG081188, Bunju, NT.

Pseudokarst Sandstone



Polygonal walls: polygons of cemented *laterite* surround soft basins. KGS841404, Lake Buchanan, Qld.

Pseudokarren: on a small pillar. KG080782, Limmen S, NT. (10 cm scale)



sheltered places). See photo KG080268, **0782**, 3291. When formed on pillars, the result looks remarkably like that of a speleothem column (photo KG081740, KG082098) but is erosional not depositional. Faint vertical striations (1-2mm wide) also occur at Limmen West and resemble *microkarren*. The origin is uncertain, but it is possibly a type of *tafoni*, influenced by vertical flow of sheets of water? cf. *karren* for solution-sculptured forms.

Pseudokarst: *Karst landforms* produced by processes other than solution (cf *parakarst* and see Grimes, 1997 and Doerr & Wray, 2004). Minor solution may also be involved. For sandstones and granites there is generally an early stage of chemical weathering, including solution, which is followed by physical erosion of the softened material (see *arenisation*).

Quartzite: A type of quartz *sandstone* which is very hard as a result of pervasive *cementation* by silica (fine quartz) between the grains. cf. *silcrete* where the cement is restricted to a near-surface band (*duricrust*).

Rising: Another term for a *Spring*.



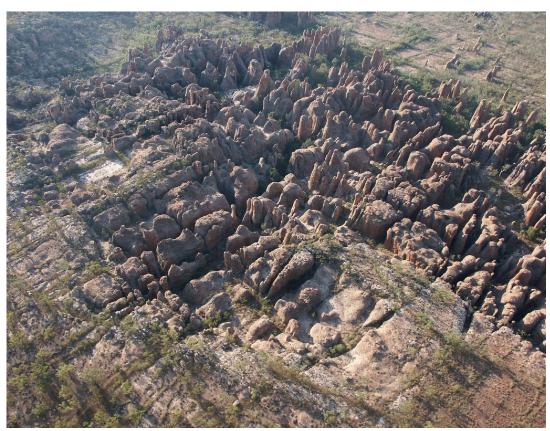
Rock shelter: A shallow cave in a cliff. KG082374, Keep River, NT.

Rock Shelter: A cavity in a cliff (or under a block) that is excluded from the term *cave* if its entrance width or height is greater than its depth into the cliff (W>L). Usually day-lit or twilight at least – occasional dark zones might occur if there is rockpile or smaller passages at rear (but the latter might qualify as caves?). Photo KG082374.

Ruiniform: A broad term (Mainguet, 1972) for sharply dissected, structurally controlled, landscapes of the giant grikefield, stone city and stone forest type, which are characterised by numerous vertical-faced blocks and pinnacles of rock separated by joint-controlled fissures or wider eroded areas. See also labyrinth karst for a karst-specific form. See photo KG080565a and Figure 8 (next page) for the full gradation from high-level pavement – grikefield – stone city – stone forest – low-level pavement with scattered pinnacles. The subtypes (giant grikefield, stone city and stone forest) all have gradational boundaries, and making the divisions is a subjective matter influenced by many factors (e.g. the ratio between the widths of the fissures and the blocks, the ratio of depth to width of both streets and blocks, and the absolute height and shape of the blocks). One possible approach, using only the ratio between street and block widths, is illustrated in figure 8.

Runnel: A type of *karren* comprising a linear trough running across a rock surface (photo KG080378, KG080407). They come in a variety of sizes and forms: linear, sinuous or meandering, and can be flat or round bottomed. Karst nomenclature has many specialised terms for variants which are less common on sandstone. We use "runnel" here as a general term for all variants. On sandstone, it is not always easy to distinguish if the process forming a runnel is solution or stream erosion.

Sandstone: A sedimentary rock formed from sand-sized grains. The composition varies. A quartz sandstone has more than 90% quartz. The remainder being



Ruiniform terrain: showing the progressive change in ruiniform character from a high-level pavement (foreground), through giant grikes, stone city and stone forest to a distant low-level pavement with scattered pinnacles.

Note the strong structural control exerted by the rectangular set of joints.

KG080565a. Abner Range, NT. The width of the dissected belt is about 400m. (aerial view).

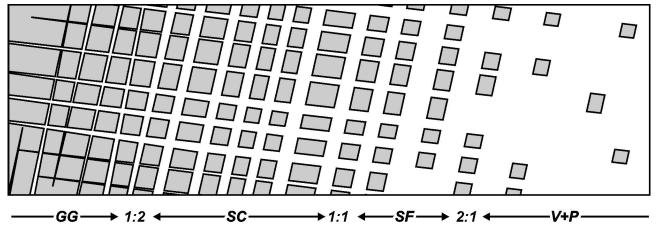


Figure 8: Ruiniform types: Gradations between *giant grikefield* (GG), *stone city* (SC), *stone forest* (SF) and *pavement* with scattered *pinnacles* (V+P). Ratios are those between the width of the streets (or low ground, shown in white) and the blocks (high ground, shown in grey), but the distinctions are quite subjective.



Runnel: This small channel was cut in sandstone by overflow of water from a pothole. KG080407, Abner Range, NT.

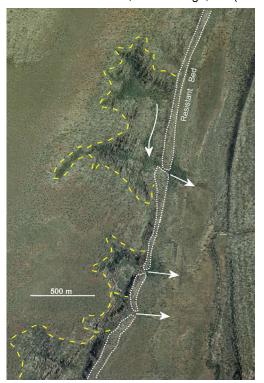
labile grains such as feldspar or rock fragments that break down more easily than quartz when chemically weathered. Labile sandstones weather differently to the quartz sandstones.

Scarp-marginal basin: (new term) An enclosed, flat-floored, steep-sided, erosional amphitheatre with a jagged outline, found near a plateau edge, with a narrow exit through a resistant barrier or bed (photo RW081870, next page). Above the exit, headward erosion and *spring sapping* widen the basin to eventually produce a flat sandy-floored area walled by steep cliffs and narrow gullies. NB all the *ruiniform* stages of Figure 8 can be preserved in the walls of the basin.

Sheeting Slickrock surface



Scarp-marginal Basin: Arrow shows drainage through the resistant bed, with an erosional basin expanded behind it. RW081870, Abner Range, NT. (aerial view).



Scarp-marginal Basin: Air photo. Yellow lines outline the basins. White dotted line is the resistant bed. Arrows show drainage. Abner Range NT.

Sheeting: AKA exfoliation, spalling. Slabs of rock splitting parallel to the surface of an outcrop. Results from physical or chemical stresses, including fire.

Shelter: See Rock shelter.

Silcrete: A type of silicified *duricrust*. cf. *quartzite*.

Sinkhole: See *Doline*. Not the same as a *stream-sink*.

Slickrock surface: Smoothly sloping, bare rock surface, possibly with fine sculpturing (tessellations, elephant hide, pits and runnels) and etching of bedding (photo KG084286P). Low-angle ones are pavements. Differs from a dip slope in that it cuts across the bedding.



Slickrock surface cut across horizontally-bedded sandstone. KG084286P, Salvator Rosa, Qld.



Slot canyon: 3-5 m wide at base. KG083512, Cobbold Gorge, Qld.

Solution pipes: vertical pipes in a laterite duricrust. KG083098, Castle Rock, NT.



Slot canyon Stone city



Spring: An outflow of water from a small *conduit* (top right) in sandstone. The orange colour is flocculated material. KG080089, Lawn Hill, Qld.



Steephead: *Spring sapping* at the head of this valley has formed a cliff. Arrow shows stream flow. KG082538, Osmond Range, WA. (aerial view).

Slot Canyon: Narrow stream-eroded canyon in a sandstone that is poorly cemented but is still able to support a vertical face. Photo **KG083512.**

Solution pan or basin: See Kamenitza.

Solution Pipe: (see *pipe*). Small smooth-walled vertical cylinders, typically 0.1 to 1.5m wide, and one or more metres deep (photos **KG083071**, page 13, **KG083098**). They may be empty or filled with breccia, rubble, nodules or soil. In analogy to *syngenetic karst* pipes, they are thought to form from focused vertical gravity flow of water that dissolves the rock, but the cause of the focusing can be varied.

Speleothem: A chemical deposit within a cave or rock shelter. In the present context these are mainly small knobby coralloid deposits of silica and other minerals (photo IH08072008_33, page 5, KG083432) but some flowstones (IH21062008_06, KG080099) and small stalactites and stalagmites were seen. Some surface silica deposits are also loosely referred to as "speleothems"



Speleothem: soft orange flowstone in a sandstone cave,. IH21062008_06, Lawn Hill, Qld.



Stone City: Sandstone **blocks** separated by **streets** RW083223, Bunju, NT. (aerial view).

Spring: Occurs where water from an *underground* drainage source re-emerges at the surface. The source may be a well-defined point or linear opening (such as a karst-like *conduit*, or an open joint or bedding plane, photo **KG080089**) or may be a more diffuse seepage over a larger area.

Spring Sapping: The undermining of a cliff or slope by water flowing out from the porous rock or sediment. cf. *Steephead*.

Steephead: A spring-fed valley that terminates upstream at a steep slope or cliff. It results from *spring sapping*. Figure 2 (page 2) and photo **KG082538**.

Stone City: AKA "Rock City", "Ruined City", "Lost City" etc. A composite *ruiniform* (q.v.) landform comprising a grid pattern of joint-controlled *streets* (corridors) separating *city blocks* or large *pinnacles*

Stone City Components

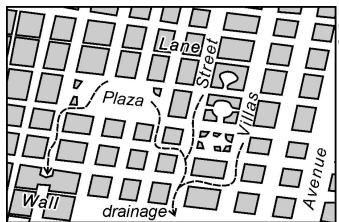


Figure 9 (left): Components of a Stone City

block block + doline doline + cave

Below: Villas, left to right:
1: floor at street level,
2: floor above street level,
3: multi-entrance with pinnacled top,
4:degraded to isolated pinnacles.

Fig. 10 (right): Modifications to Blocks & Villas

Component features of a stone city include some new terms coined for this report, using a "city-oriented" terminology (Figures 9 & 10). See Grimes *et al*, 2009.

The streets and open areas.

Streets, (q.v.) A general term for the main joint-controlled corridors (photo **KG080733** page 20, KG080734P). AKA *giant grike, box valley,* etc.

Avenues, broader corridors than the average streets, AKA *box valley* (q.v.), photo RW083425a and satellite image on page 3.

Lanes, narrow cross-cutting corridors (photo KG080726a) – there is commonly a pattern of broad streets running one way, and more narrow lanes running across them. If considered alone, many lanes might count as *giant grikes*;

Plazas, (q.v.) open, flat-floored (or rubble-strewn) spaces where one or more city blocks have been removed by erosion (photo **KG080566**, 1178-9 & **1188**, see page 13). A particularly large plaza at Bunju (300 x 600 m) has been referred to informally as the "big park" (photo RW083467a).

Barrier walls, (q.v.) this term is used here for walls of sandstone that block a city street (Fig 9), possibly restricting the through drainage to a narrow fissure, or forcing it to go underground through a cave (Photo KG080779, page 2);

The blocks and their contents.

City blocks, the large upstanding blocks left between the streets and lanes, may be solid or dissected into pinnacles, villas, dolines etc. (photos KG080566, 0568, RW083223, page 17);

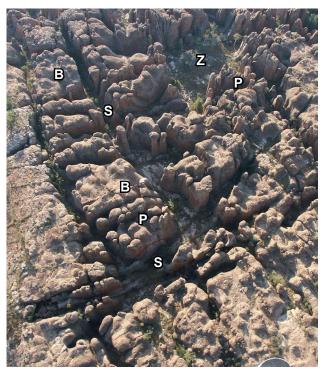
Villas, (q.v.) hollow city blocks, with one or more narrow entrance lanes (or cave passages) leading to a central courtyard that has a flat(ish) floor that can be at, or several metres above, the street level (see figure 10). The name is taken from the old Roman

villas with a central courtyard (e.g. at Pompeii). (Photos KG080693, **0737**, **0743P**, see page 23).

Dolines, (q.v.) both collapse and solution *dolines* occur within city blocks and can be circular or elongated along a joint. This includes enclosed *villa courtyards* accessible only via a short cave (Photos KG081188-90, 1222, 1225,26; RW083296);

Caves, (q.v.) may penetrate through the blocks or barrier walls, or connect adjoining villas;

Pinnacles, (q.v.) these may be isolated at street level (e.g. within a *plaza* or as the degraded walls of a *villa*), or forming on the tops of the city blocks (as roof turrets, photo **KG080566**);



A Stone City: Steep aerial view. Streets & lanes (S), Blocks (B), Pinnacles (P), Plaza (Z). KG080566, Abner Range, NT.

Stone Forest Structural control



Stone Forest: A field of conical *pinnacles*. KG081182, Bunju, NT. (aerial view).

(towers). Photo **RW083223** page 17 and image on page 3. As the streets become narrower it grades to a giant grikefield when the blocks are broad enough to dominate over the corridors, or alternatively it grades to a stone forest as the streets expand to form a field of spaced pinnacles (Figure 8). See photo **KG080565** in the ruiniform entry (page 15) for the full gradation from high-level pavement – grikefield – stone city – stone forest – low-level pavement with scattered pinnacles.

Component features are listed on page 18.

Stone Forest: (new term for sandstone, but cf. Chinese karst usage: shi-lin, photo KGS840602). A composite landform comprising a field of closely spaced *pinnacles* (photo KG080559, KG081182, RW083357). Grades to *stone city* when the width of the *streets* between the blocks/pinnacles becomes less than the width of the pinnacles (see figure 8)

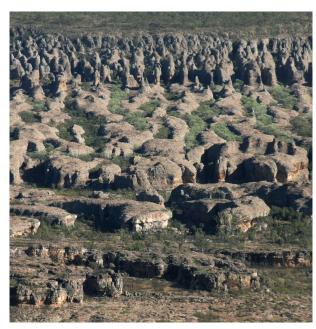
Stratigraphic control: Occurs where the landforms are controlled by differences in the rocks between neighbouring beds or strata (Figure 11). Best seen at Bunju, where different strata show different styles of weathering: e.g. pinnacles in one strata above linear giant grikes in the next above a dip-slope pavement on a resistant bed. Photos RW083357, 3359, **3377**. See also *structural control* and note that the two controls can act together.

Stream capture: Occurs when an actively incising stream cuts into an adjoining, older, less active valley and diverts its flow into the new course. The old valley may be left dry or with a reversed drainage – a type of *paleodrainage*. Examples are seen at Cobbold Creek. Underground stream capture occurs when a cave or *stream-sink* captures a surface flow, to form a *blind valley*, as at Whalemouth and Lawn Hill.

Stream-sink: The point where a surface stream disappears underground into a cave or impenetrable hole. See also *underground drainage*, Figures 2, 13.

Street: AKA *giant grike, box valley*, bogaz. Used here as a general term for the linear flat-floored areas between the *stone city* blocks. The size varies from narrow *lanes* to broad *avenues*. Photo **KG080566**, **0733** (next page), 0734P and Figure 9.

Structural control: Occurs where the shapes of the landforms are influenced by geological structures such as joint patterns or faults, or by planation levels controlled by the stream base level (e.g. *pediments*.). The rectangular patterns of stone cities and grike fields are structurally controlled by joint sets. Photos



Stratigraphic Control: Different types of sandstone form different topography – stone forest, giant grikefield, stone city. RW083377, Bunju, NT. (aerial view).

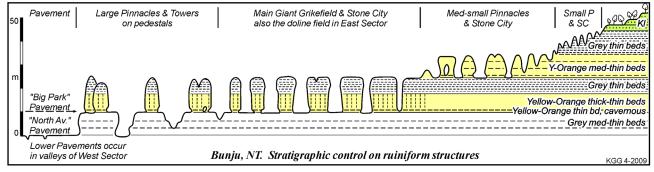


Figure 11: Stratigraphic Control. At Bunju, different beds have different landforms (cf. photo RW083377 above).

Subjacent Karst Tessellations

KG080565a (p. 15), **0566** (p. 18), 0573, RW083223. A special type is that producing tilted pinnacles. The pinnacles are aligned to the joints, which in turn are perpendicular to the bedding which is dipping (photo **KG080527**). cf. *stratigraphic control*.



Structural Control: The tilted **pinnacles** are controlled by tilted joints and beds. KG080527, Abner Range, NT.



Street of a stone city. KG080733, Limmen South, NT.

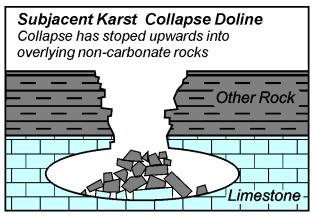
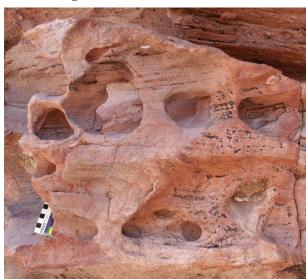


Figure 12: Subjacent karst collapse.

Subjacent karst: Refers to *dolines* that form in sandstone and other rocks that overlie limestone or dolomite. Solutional cavities originating in the limestone can migrate upwards (a process called stoping) through the sandstone by progressive collapse of the cavity ceiling and build-up of rubble on the floor, until they intersect the surface to make a collapse doline (Figure 12).

Syngenetic karst: A form of karst found in soft calcarenites (carbonate sandstones) and characterised by the development of caves and karst features at the same time as the sand is being cemented into a rock. Of interest here as there are analogies to the processes and features found in *laterite karsts*, especially the *solution pipes* and *laterite pinnacles*.

Tafoni: In this report used for individual small to medium sized weathering hollows on a rock surface (photo **KG082336**, 4357, 4530). See discussion under *Cavernous Weathering* (and in Goudie, 2004, and Young et al., 2009, p.144) for other terms and variations in usage in the literature. cf. *honeycomb weathering*.



Tafoni: KG082336, Keep River, NT.

Talus: AKA Scree. A body of rock fragments moving down a steep slope under gravity.

Talus Cave: A type of *boulder cave* that occurs in coarse-grained talus in scree slopes or infilling valleys (see Grimes et al., 2009, p.37, and Halliday, 2004).

Tessellations (Tessellated surfaces): A pattern of superficial cracks, which penetrate no more than a decimetre into the rock, and which may be partly opened up by weathering (Branagan, 1983). The pattern may be polygonal (e.g photo KG083630, 3665, 3777J) or rectangular (the latter, sometimes called *elephant hide*, may involve a combination of horizontal bedding grooves and vertical cracks on a cliff that gives a tiled pattern, e.g. photo **KG084573**, 4638).

Toppling Tubelet



Tessellations: Polygonal type on a shallow slope. KG083777J, Cobbold Creek, Qld.

Toppling: The rotation and eventual fall of a tall *block* or *pinnacle* as its base is undermined. Toppled blocks may slide some distance down a *talus* slope. cf. *cambering*.

Tor: (special usage in this report) a pile of separate rocks, much jointed. We use *pinnacle* or *tower* for solid ones. Photo, N. White, below.

Tower: A large steep-sided hill; a large *pinnacle*. Photo **KG082358P**, 2382. Photo KG084349 is at the borderline between a small tower and a large pinnacle.



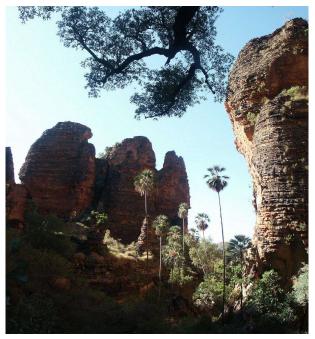
Tor: A "pinnacle" formed from a pile of individual blocks. Photo © N. White, 1992, Gregory Karst, NT.



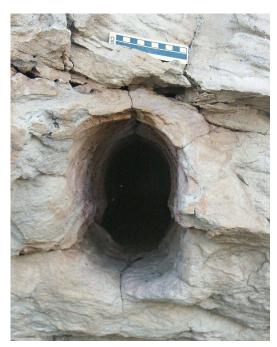
Tessellations: Rectangular type on a vertical cliff. KG084573, Mt. Moffatt, Qld.

Tube: (special usage in this report) A small (W<0.3 m) conduit of round to oval cross-section (photo **KG084622** next page). cf. *fissure* which has a more elongated cross-section. cf. *pipe* for a special type of tube that is vertical and cylindrical (i.e. *solution pipes*). Very small ones are *tubelets* (W<=2 cm). Good examples of straight horizontal tubes occur at Salvator Rosa & Mt. Moffatt (e.g. photo KG084329b, 4624).

Tubelet: (special usage in this report) Very small tubes (W <=2 cm), usually in sets, that may run parallel to bedding or a joint, or be irregular 3-D networks



Towers: KG082358P, Keep River, NT.



Tube: Straight horizontal *conduit* in sandstone. KG084622, Mt. Moffatt, Qld. (10 cm scale)



Tubelet: Small horizontal & inclined tubelets, with *case-hardened* rims. KG080258, Caranbirini, NT. 10 cm scale

in a mass of sandstone. Many have smooth coated surfaces or thin cemented rims. They also occur in *laterite DWP*s, where some authors attribute them to termite burrows (photo KG088060, 3061). These are equivalent to the proto-conduits of limestone karst and together with *tubes* and larger *conduits* they make an important part of *underground drainage*. Good examples at Caranbirini (Photo **KG080258**), West Limmen (KG080839-41), and Mt. Moffatt (KG084616).

Tufa: A soft, porous *chemical deposit*, mainly calcareous possibly with some vegetable matter, but also can form from siliceous or ferruginous materials.

Underground drainage is the most distinctive hydrological feature of karst areas. Surface streams are rapidly lost underground through *stream-sinks* and the water flows beneath the surface in *conduits* to reappear in *springs*, figures 2 & 13. Parts of the original surface drainage may remain as *blind valleys* and *dry valleys*.

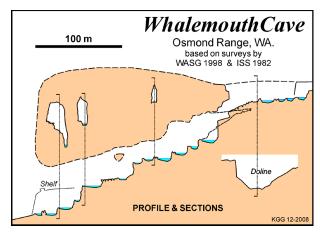
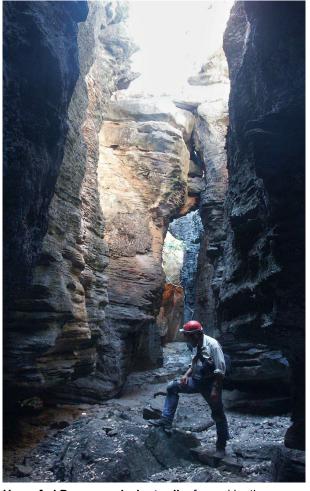


Figure 13: Underground drainage. Profile of a stream-cave in sandstone. The stream sinks at the top right, at the end of a *blind valley*, and rises from the cave mouth at the lower left.



Unroofed Passage: A **giant grike** formed by the collapse of a cave roof. KG051532, Gregory Karst, NT.

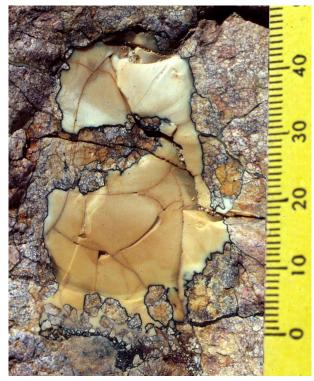
Unroofed Passage Vug

Unroofed Passage: A *giant grike* that formed by the collapse of a cave ceiling. Photo **KG051532**.

Vadose: In hydrology, the vadose zone is the upper zone, above the watertable and *phreatic zone*, where the porosity contains both air and water (Figure 6, page 10). The water is generally moving downwards towards the permanent aquifer, but may be diverted into horizontal flow along *conduits*.

Villa: (new term) See also *stone city components* (*villa*). A stone city block with a central open space, connected to the streets via narrow lanes or short caves and with a floor that can be several metres higher than the streets. The walls can be from 2-10 m thick. Figure 10 and photos KG080693, **0737** & **0743P**). Genesis would seem to involve a broad-scale *case-hardening* of the block followed by erosion of the softer core.

Vug: A small solutional cavity, possibly lined with crystals (in limestone) or clay or other material (in *laterite karsts*) or be completely filled with younger chemical deposits (photo KGS830230). They may be associated with networks of small *tubelets*. Photo KGS900317 is of a vuggy porosity in a laterite.



Vug: Opal-filled cavity in a *deep weathering profile*. KGS830230, Donors Plateau, Qld. Scale in mm.





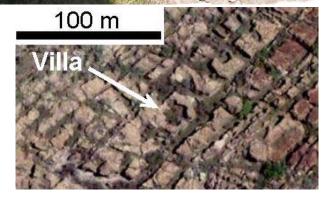
Villa: Three views of a villa, Limmen South, NT.

Bottom Right: Satellite image of the villa within its **stone city** setting. (1m pixels).

Above Left: (KG080737a) is its south-eastern entrance as seen from the stone city street. Note the villa floor is one metre above the street level in foreground.

Above Right: (KG080743Pa) is a view looking south inside the villa, showing courtyard and bounding walls.

NB: photo KG080733 on page 19 is of the big street on the SE side of the villa.



Wall Wind gap

Wall: (see both barrier wall and cemented wall)

Watertable: The top of the permanently saturated (*phreatic*) zone. Figure 6, page 10.

Weathering: A term for the breakdown of a solid rock into softer or fragmented material which is more easily eroded. There are two main types: Chemical weathering involves chemical changes, including solution, which may destroy the *cement*, or produce new, often softer, minerals. Physical weathering involves the mechanical break-up of the rock or its grains into loose fragments. See also *deep weathering*, which is mainly chemical.

Wind Erosion: Wind erosion can form *lunettes* and spectacular sculptured forms but in the region studied it appears to have had only a minor influence.

Wind Gap: A section of abandoned *dry valley* left after stream capture, especially where it crosses a drainage divide.

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