Cadernos Lab. Xeolóxico de Laxe
Coruña. 2017. Vol. 39, pp. 165 - 176 ISSN: 0213-4497

On the meaning and use of the terms, 'erosion'and 'exhumation'

TWIDALE AND, C. R. and BOURNE, J. A.

(1) Geology and Geophysics, School of Physical Sciences, University of Adelaide, North Terrace, Adelaide 5005, South Australia.
Telephone: 618+8313 5392; Fax: 618+8313 4747; email addresses: rowl.twidale@adelaide.edu.au,

Key words: exhumation; erosion; etch; unconformity; discontinuity

Abstract: It is important that technical terms with agreed meanings are used correctly. This applies particularly to words that reflect their etymology. Neglect of this principle distorts information and compromises the discussion, understanding, and value of otherwise useful papers and reports. In discussion and in publications, some authors have used the term 'exhumed' as synonymous with 'erosional', whereas in disciplines like stratigraphic geology and geomorphology the two are perceived as having quite different meanings and implications for chronological reconstructions. Furthermore, some aspects of the nature of erosion do not appear to be appreciated.

PROBLEM

There is insome quarters confusion as to the meaning of, and difference between, 'erosion' and 'exhumation' and their derivatives. 'Erosion' is the wearing away or lowering of a surface, whether of, say, a boulder or cobble, a platform or pediment, or a landscape. The word is derived from the Latin *erodere,* to gnaw or wear away. To exhume on the other hand is to extract out of the ground, to disinter, resurrect, or re-expose, for etymologically *humare* is the Latin for 'to bury', *humus* is the ground, and '*ex*' in this context means 'out of'. Thus, occasionally the authorities order a corpse to be exhumed, that is, disinterred, for further examination. In geology and particularly in geomorphology, the word in used in the same sense. Exhumed landscape features have been shaped by destructive (erosional) or constructive or depositinal processes active at or near the land surface, buried, for example by marine or lake sediments or by volcanic lava or ash, and later re-exposed. Accordingly, an exhumed surface is an exposed unconformity and as such represents an hiatus or break in time.

Unfortunately, surfaces that clearly are erosional in origin have been described as exhumed. It serves no purpose to cite specific papers and authors for what is perceived to be the incorrect and misleading application of technical terms is surely unintentional. But by way of illustration and exemplification the following phrases are quoted from recently published papers that contain much of interest and value but in which 'exhumation' clearly but disconcertingly is intended to indicate 'erosion' or the wearing away of the rock. In none of the instances cited is an earlier exposed phase envisaged. Thus, reference is made to the elastic response of brittle rock causing 'the magnitude of all three principal stresses to reduce at different rates during exhumation', to 'exhumation induced stresses', to an 'exhuming rock landscape' and to a rock passing though a physical transition – possibly a discontinuity of the type discussed below–at an estimated depth of 10 km 'during a period of rapid exhumation'. Again, a flared slope has been described as 'A concavity… produced by subsurface weathering and subsequent exhumation' though again, the bedrock form has not previously seen the light of day.

EROSIONAL PROCESSES

Erosional processes cause the lowering of the land surface. They are generated at the Earth's surface and are epigene processes that have produced, degraded or destructional forms. Two general points call for attention. First, overwhelmingly erosion is preceded by and is dependent upon prior weathering, the disintegration and or the alteration of the country rock. Without such preparatory weathering there would be little erosion, save in the bedrock channels of major rivers where potholes, Rillen or grooves, and scallops are formed (Figure 1) and more generally as a result of catastrophic or storm events such as major floods (e.g. BAKER, 1973). Second, erosion at one site or in one area implies deposition elsewhere For example, upstream catchments are lowered, but the eroded detritus is carried downstream and eventually laid down either in stream channels in piedmont zones as alluvial fans, in valley floors, or in the sea.

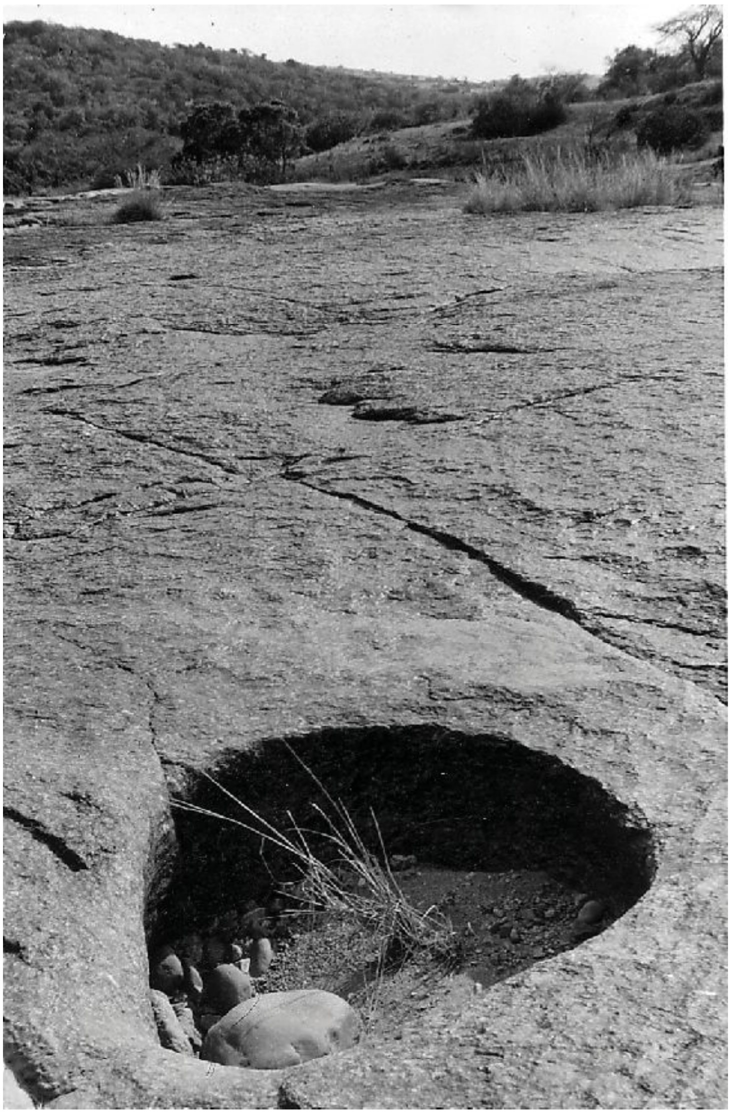

Fig. 1. (a) Pot hole in granite in the bed of the Umgeni River, Kwa-Zulu Natal, Republic of South Africa. (b) Parallel grooves cut in granitic bed of the Ashburton River, at Nanutarra, western Pilbara, Western Australia (c) 'Scallops' shaped in granite exposed in river bed, Davies River, north Queensland.

Rivers are the dominant agency shaping the land surface of humid and temperate areas, though not to the degree stipulated by some workers (e.g. DAVIS, 1909, pp. 266-267; but see also BLISS KNOPF. 1924). The turbidity of rivers in flood shows that they transport silt and sand in suspension and by saltation and the coarser debris is carried as the bed or traction load (e. g. MORISAWA, 1968). Rivers in the more usual range of discharge and velocity, and particularly those armed with coarse detritus, have gouged potholes, gutters, and scallops in coherent bedrock exposed in main channels, but the erosional capacity of small discharge and lower velocity streams, and of surface wash, appears to be limited to friable fines (BAKER, 1988; NOLDHART and WYATT, 1962). HILLS (pers. comm,. 1962) characterized the changes in erosion on divides washed by minor streams and overland flow by stating that there is 'first of all a period of rapid skimming off of the soil and rotten rock, followed by a sudden decrease in removal of detritus when fresh rock is exposed…'. Thus, like some glaciers, rivers tend to act as bulldozers rather than excavators (BOYÉ, 1950). Both agencies are capable of picking up and transporting weathered detritus but are ineffective where in contact with coherent rock.

This implies that many regoliths that were not so weathering as to produce a duricrust (laterite, silcrete, calcrete etc) have been stripped to produce a bedrock surface of etch type, that is, one formed at the *Tiefenfront* or weathering front at the base of the regolith (BÜDEL, 1957; MABBUTT, 1961; Figure 2). 'Etch' because the front is shaped by etching, that is, by chemical alteration of some or all the rock-forming minerals, though in many instances with significant chemically-induced physical effects (e. g. HUTTON et al., 1977). Many – some workers would say 'most'–familiar landforms at various scales are of etch type (e. g. TWIDALE 2002), and others have been attributed to partial etching (e. g. TWIDALE and CAMPBELL, 1998). As long as a regolith remains in place the bedrock surface beneath continues to evolve, but where the cover has been stripped the etched bedrock surface, no longer in constant contact with moisture, becomes relatively stable (e. g. LOGAN, 1851, p. 326).

Fig. 2. (a) An example of an etch landscape at The Granites near Mt Magnet, Western Australia, where a blocky granitic surface is exposed as a result of the stripping of a lateritized and kaolinized regolith preserved in plateau remnants. (b) Corestones exposed in a road cutting near Pine Creek, Northern Territory, Australia, provide and example of forms defined by a discrete weathering front, that give rise to surface forms in corestone boulders. That the corestones are in situ and not transported is confirmed by the intrusive vein.

Glaciers, wind, and waves also call for consideration. As with rivers none is significantly effective without prior weathering. Even in the climatic extremes represented by the midlatitude deserts and glaciated lands, rivers have played a significant role in landscape evolution. Though glacial and fluvioglacial deposits are differentiated the former are initiated by ice melt but have not been subjected to the sorting action of running water. In addition sub-glacial melt water flows are responsible for the complex and incongruous channel patterns of some deglaciated lands (e. g. DERBYSHIRE, 1962). Similarly, no desert is rainless and the occasional brief but violent river flows have left their indelible imprint on the landscape (e. g. PEEL, 1941). Also, the erosional impacts of the wind are frequently misunderstood. Only in special circumstances are specific landforms shaped by the wind in coherent rock (e.g. RUSSELL, 1932; BOBEK, 1969; BREED et al., 1989). On the other hand, millions of tonnes of fines are transported long distances (even intercontinentally) in dust storms, implying a general lowering of the land surface in the source areas.

The impacts of storm waves are legendary and have long been recognized (e.g. JOHNSON 1919) but wave action and other shoreline processes are restricted to the margins of the continents and even there are significant only on exposed coasts (e. g. DAVIES, 1964).

In summary however most landscapes have been shaped by stream erosion in its various forms (concentrated channel flows, diffuse wash, and so on), and the type and intensity of erosional processes has varied in time and space, but all have resulted in the lowering or wearing away of substantial sectors of the land surface. This is very different from the formation, by either erosion or deposition, of a surface, its burial, and later re-exposure, indicated by the term 'exhumed', and with all the chronological implications associated with it.

EXHUMED SURFACES

Though they are widely distributed in time and space exhumed features vary in extent. They range in age between Late Archaean, as on the Pilbara Craton of Western Australia, to Early Pleistocene, as on northwestern Eyre Peninsula (TWIDALE and CAMPBELL, 1984; TWIDALE, 1986). Many occur at site-scale, as for instance inselbergs shaped in Early Paleozoic granites now exposed from beneath Miocene strata in and near the gorge of the lower River Murray in South Australia. Remnants of various sub-Proterozoic ages are reported from Arctic North America (AMBROSE, 1964), and the Barrow Creek area of the Northern Territory (Figure 3). In the latter area a glaciated landscape eroded in Paleoproterozoic quartzites has been exhumed from beneath later Neoproterozoic sediments. It is claimed that the present exhumed landscape must resemble that of some 600 million years ago, except that there is now no ice (THOMPSON, 1991, p. 85). Sub-Cambrian landscape elements are prominent in southern Sweden (RUDBERG, 1970) and in the central Sahara (BEUF et al., 1971). A sub-Triassic inselberg landscape is prominent in the Linares–Ubeda district of southern Spain (AZCÁRATE, 1972). The exhumed surface of Charnwood Forest in the English Midlands is also of sub-Triassic age (WATTS, 1903). The Cretaceous saw several extensive marine transgressions and features of various sub-Cretaceous ages are reported from, for example, southern Sweden (LIDMAR-BERGSTRÖM, 1989) and at the western margin of the Great Australian Basin (TWIDALE and BOURNE, 2013), and in the northern Pilbara region of Western Australia (Figure 4).

Fig. 3. Surface of blocky gneiss exhumed from beneath flat-lying quartzitic sequence forming a plateau, near Barrow Creek, Northern Territory, Australia.

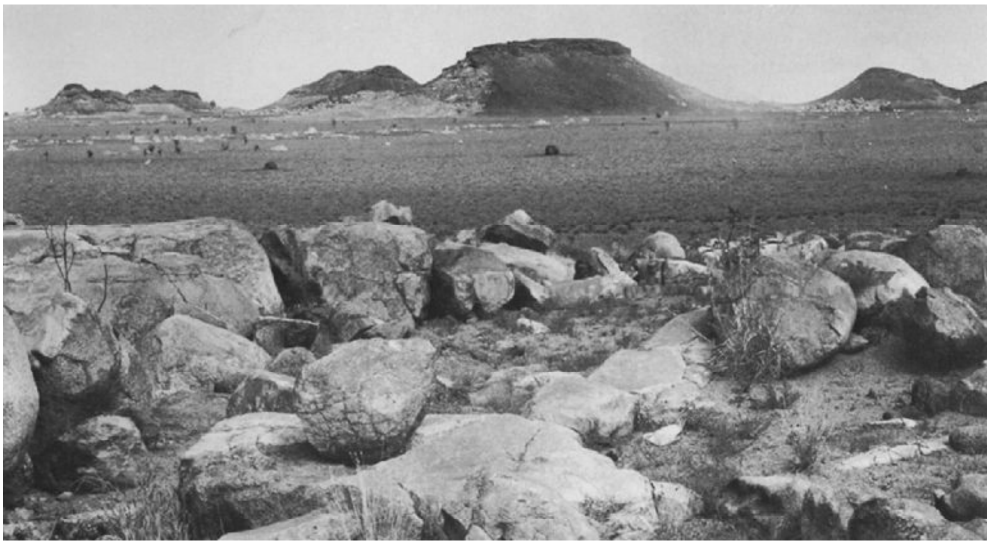

Fig. 4. Boulder-strewn granite hills in process of exposure from beneath flat-lying Cretaceous sediments east of Karratha, Western Australia.

Whatever their extent, such disinterred forms are of chronological significance. The age of an exhumed surface is bracketed by the age of the youngest rock transected by the surface and the oldest rock overlying it. Most commonly the surface just precedes the youngest member of the cover sequence. Cover by lava or ash allows the preservation of quite fragile forms such as desert dunes (e. g. ALMEIDA, 1953; JERRAM et al., 2000). The conservation of delicate decorations like those developed in the Tindal area, near Katherine, in the Northern Territory, on miniature towers in Cambrian limestone and that have been re-exposed from beneath a cover of marine Cretaceous beds remains unresolved (TWIDALE 1984).

Some unconformities are complicated by the occurrence of a zone of alteration, usually developed on the buried surface. Whether such horizons existed prior to, and were preserved by, burial, or are the result of groundwaters percolating along the physical parting, that is, the unconformity, is in many instances difficult to determine. Where the weathered zone occurs on a steeply-dipping unconformity and extends to depth (e. g. LASCELLES, 2014), it clearly predates burial. Its composition may indicate the climate that prevailed during its evolution.

DISCONTINUITY AND UNCONFORMITY

Reference has been made to rock passing through a physical transition at depth 'during rapid exhumation'. Was the transition envisaged similar to the intrusive contact between the Hiltaba Granite (*ca* 1585 ma) and the Gawler Range Volcanics (*ca* 1592 ma) (Figure 5)? The contact is a discontinuity and not an unconformity. For though it represents a time gap of some seven million years it was never exposed as a surface and was not revealed in section until the Early Cretaceous, following the dissection responsible for the present gross relief of the upland (CAMPBELL and TWIDALE, 1991). Moreover, and as is explained in the discussion of the nature of epigene erosion, rapid erosion could not have taken place without prior weathering, which implies exposure.

DISCUSSION AND CONCLUSION

An unconformity implies an hiatus, a gap in the chronological sequence. Etching implies a time period during which a weathering front was shaped beneath a regolithic cover that was later stripped and the underlying topography exposed. Accordingly, though a clean unconformity represents a time gap, as most erosional bedrock surfaces are of etch origin, the so-called hiatus includes a phase of weathering and erosion and may be of considerable duration.

Although science cannot be studied in clearly defined and isolated sections, the meanings attached to some technical terms words used in related yet separate disciplines differ. This can lead to misunderstandings. 'Exhumed' and 'eroded' and their derivatives are but examples. Language is ever in flux but some constants are not only welcome, but critical.

REFERENCES

ALMEIDA, F. F. M., 1953, Botucatú, a Triassic desert of South America: *XIX International Geological Congress, Algiers VII*, 9–24.

AMBROSE, J. W., 1964, Exhumed palaeoplains of the Precambrian Shield of

North America: *American Journal Science,* 262, 817–857.

AZCÁRATE, J. E., 1972, *Ubeda E1:50,000, Mapa Geologico de Espana*: Instituto Geologico y Minero de Espana, Madrid.

BAKER, V. R., 1973, Paleohydrology and sedimentology of Lake Missoula flooding in eastern Washington: *Geological Society America Special Paper* 144. 79 p.

BAKER, V. R., 1988, Flood erosion. In Baker, V. R.; Kochel, R. C.; and Patton, P. C. (Editors), *Flood Geomorphology*: Wiley, New York. 81–95.

BEUF, S.; BIJU-DUVAL, B.; DE CHARPAL, O.; ROGNON, P.; GARIEL, O.; and BENNACET, A., 1971, *Les Grès du Paléozoïque Inferier au Sahara:* L'Institut Français de Pétrole, Paris, France. 464 p.

BLISS KNOPF, E., 1924, Correlation of residual erosion surfaces in the eastern Appalachians: *Geological Society America Bulletin,* 35, 633–668.

BOBEK, H., 1969, Zur Kenntnis der Sudlichen Lut. Ergebnisse einer Luftbildanalyse: *Mitteilungen der Österreichischen Geographischen Gesellschahft,* 111, 155–192.

BOYÉ, M., 1950, *Glaciaire et Périglaciaire de l'Ata Sund, Nord-oriental Groenland*: Herrmann, Paris, France. 176 p.

BREED, C. S.; MCCAULEY, J. F.; and WHITNEY, M. I., 1989, Wind erosion forms. In Thomas, D. S. G. (Editor), *Arid Zone Geomorphology*: Belhaven, London, UK, 284–307.

BÜDEL, J., 1957, Die "doppelten Einebnungsflächen" in den feuchten Tropen: *Zeitschrift für Geomorphologie*,1, 201–208.

CAMPBELL, E. M. and TWIDALE, C. R., 1991, The evolution of bornhardts in silicic volcanic rocks in the Gawler Ranges, South Australia: *Australian Journal Earth Sciences,* 38, 79–93.

DAVIES, J. L, 1964, A morphogenetic approach to world shorelines: *Zeitschrift für Geomorphologie* 8, 127–144.

DAVIS, W. M., 1909, *Geographical Essays*: Edited D.W. Johnson, Dover, Boston, 777 p.

DERBYSHIRE, E., 1962, Fluvioglacial erosion near Knob Lake, central Quebec-Labrador, Canada: *Geological Society America Bulletin,* 73, 1111–1126.

HUTTON, J. T.; LINDSAY, D. S.; and TWIDALE, C. R., 1977, The weathering of norite at Black Hill, South Australia: *Journal Geological Society Australia*, 24, 37–50.

JERRAM, D. A.; MOUNTNEY, N. P.; HOWELL, J. A.; LONG, D.; and STOLLHOFEN, H., 2000, Death of a sand sea: an active aeolian erg systematically buried by the Etendeka flood basalts of NW Namibia: *Journal Geological Society London,* 157, 513–516.

JOHNSON, D.W., 1919, Shore Processes and Shoreline Development. Wiley, New York. 584 p.

LASCELLES, D. F., 2014, Paleoproterozoic regolith beneath wave cut erosion surfaces preserved on the northern margin of the Yilgarn Craton, Western Australia: *Australian Journal Earth Sciences,* 61, 843–863.

LIDMAR-BERGSTRÖM, K., 1989, Exhumed Cretaceous landforms in south Sweden: *Zeitschrift für Geomorphologie*, 72, 21–40.

LOGAN, J. R., 1851, Notices of the geology of the Straits of Singapore: *Proceedings Geological Society London,* 7, 310–344.

MABBUTT, J. A., 1961, 'Basal surface' or 'weathering front': *Proceedings Geologists' Association London,* 72, 357–358.

MORISAWA, M. 1968. Streams, their dynamics and morphology. McGraw-Hill, New York.175 p.

NOLDHART, A. J. and WYATT, J. D., 1962, *The geology of portion of the Pilbara Goldfield*: Geological Survey Western Australia Bulletin 115. 199 p.

PEEL, R. F., 1941, Denudation landforms of the central Libyan Desert: *Journal Geomorphology*, 4, 3–23.

RUDBERG, S., 1970, The sub-Cambrian peneplain in Sweden and its slope gradient: *Zeitschrift für Geomorphologie*, 9, 157–167.

RUSSELL, R. J., 1932, Landforms of San Gorgiono Pass, southern California: *University California (Berkeley) Publications Geography,* 6, 37–44.

THOMPSON, R. B., 1991, *A guide to the geology and landforms of central Australia*: Northern Territory Geological Survey, Alice Springs, Australia, 136 p.

TWIDALE. C. R. 1984, The enigma of the Tindal Plain, Northern Territory.

Transactions of the Royal Society of South Australia 108, 95-103.

TWIDALE, C. R., 1986, Granite platforms and low domes: newly exposed compartments or degraded remnants?: *Geografiska Annaler, Series A: Physical Geography*, 68, 399–411.

TWIDALE, C. R., 2002, The two-stage concept of landform and landscape development involving etching: origin, development and implications of an idea; *Earth-Science Reviews,* 7, 37–74.

TWIDALE, C. R. and BOURNE, J. A., 2013, Palaeosurface contrasts between the eastern and western margins of the Great Australian Basin: *Transactions Japanese Geomorphological Union,* 34, 179–196.

TWIDALE, C. R. and CAMPBELL, E. M., 1984, Murphy Haystacks, Eyre Peninsula, South Australia. *Transactions Royal Society South Australia,* 108, 3 175-183.

TWIDALE, C. R. and CAMPBELL, E. M., 1998, Development of a basin, doughnut and font assemblage on a sandstone coast, western Eyre Peninsula, South Australia: *Journal Coastal Research,* 14, 1385–1394.

WATTS, W.W., 1903, Charnwood Forest, a buried Triassic landscape: *Geographical Journal*, 21, 623–633.