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SEDIMENTOLOGICAL CHARACTERISTICS OF THE "RED MUDS" AT MAKAPANSGAT LIMEWORKS

by

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ABSTRACT

The "red muds" which occur at Rodent Corner along the west face of the exit quarry at Makapansgat limeworks have been divided into two sedimentary facies according to lithology, sedimentary properties and biological content: (1) coarse sandstone; and (2) siltstone and fine-sandstone. These two facies form a depositional couplet or sedimentary motif that occurs throughout the deposits and can be used as a basis for interpretation of the conditions of deposition.

The coarse sandstone facies consists of thin lenticular beds which contain occasional elongate bone fragments showing a pronounced sedimentary fabric. This facies was probably deposited by flowing water, but, because of its coarse grain size, scale and low granulometric contrast, traction current structures such as cross-bedding and ripple cross-lamination were not developed. The angular character of the individual grains implies a short distance of transport and local derivation of the facies.

The siltstone and fine sandstone facies is red and calcareous and contains sporadically distributed coarse sand grains. It is generally thicker and laterally more persistent than the coarse sandstone facies and capped by a mudcracked surface. The general characteristics of this facies are consistent with deposition in slow-moving or standing water from quiet suspension sedimentation. Shallowing of the water, related to changes in level of the water table, led to exposure of the depositional surface and the development of mudcracks. A variation of this facies pattern occurs in the middle of the succession where two limestone layers were deposited, the upper one intimately associated with local concentrations of cave pearls which originated from the lime-rich surface waters in locally agitated pools by concentration and precipitation of carbonate about a central nucleus.

The facies couplet is interpreted in terms of storm and fair weather processes and compared with modern analogues found on shallow marine shelves, alluvial plains and in lakes. The coarse sandstone facies is attributed to storms and heavy rainfall outside the cave washing in coarse sandy detritus and raising the level of the water table. Between storm episodes quiet suspension sedimentation occurred accompanied by a gradual shallowing of the water table. Thus the coarse sandstone facies provides clues to storm periodicities and rainfall and suggests a rather wet climatic regime at this time. The red muds at Rodent Corner differ from those near the "Ancient Entrance" in that they contain coarse sandy interbeds, implying that the two deposits were separated from one another, possibly by a floor high, and that the opening into the cave at this time was small and probably located close to Rodent Corner.

INTRODUCTION

The Makapansgat limeworks cave deposits are situated on the south side of the Makapansgat valley (fig. 1) about 25 km east-northeast of Potgietersrus in the northern Transvaal (fig. 2). The deposits are important because of their rich Plio-Pleistocene vertebrate fauna and hominid remains. Although the fauna and hominid remains have been studied in detail, controversy still surrounds the origin of the cave deposits due largely to the lack of adequate sedimentological studies.

GENERAL BACKGROUND AND PURPOSE OF THIS PAPER

Brain (1958) divided the cave deposits into (1) floor travertine, (2) lower phase I breccia, (3) upper phase I breccia and (4) phase II breccia. A formal lithostratigraphic subdivision was proposed by Partridge (1975) who recognised five members of the Makapansgat Formation which consisted of the deposits filling the cave. Each member was given a number and where necessary further subdivision into beds. The lithostratigraphic subdivision proposed by Partridge (1975) has three disadvantages: (1) it is based on the American Code of Stratigraphic Nomenclature, not the South African or International Code; (2) the term "member" is not formally valid unless prefixed by a lithologic or geographic name (Hedberg 1970, S.A.C.S. 1971); and (3) the floor of the cave was uneven (Maguire *et al.*, 1980) with the result that deposition was not consistent in space or time. Thus, correlation is difficult and must contend with the problem of diachronism. In view of this a lithogenetic approach may be more useful with the cave deposits considered in terms of sedimentary facies, each facies being characterised by its lithology, sedimentary properties and biological content. This type of ap-

Figure 1. Makapansgat limeworks seen from the opposite side of the Makapansgat valley.

proach has been applied to one of the most controversial of the cave deposits, the red muds, which fall within Brain's (1958) lower phase I breccia and Partridge's (1975) member 2. The red muds have been interpreted as a subaqueous deposit (Brain 1958) with rapid discharge into a standing body of water and the development of *abundant*

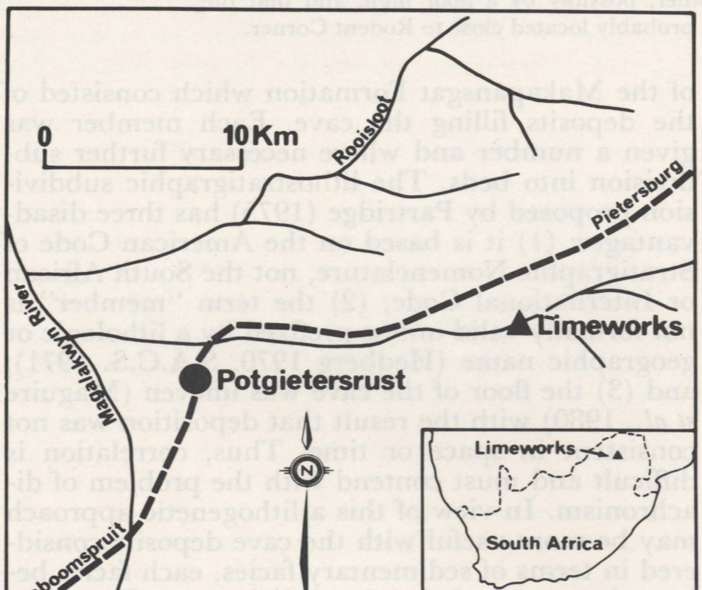

Figure 2. Locality map of the Makapansgat limeworks.

cross-bedding and deltaic units showing small-scale lateral facies changes (Partridge 1975). Ideas similar to these were expressed by Butzer (1978).

Previous descriptions of the red muds refer to them as silts and fine sands but make little mention of the coarse sand and granules disseminated throughout the rock or concentrated into thin laterally persistent lenses (Brain 1958, Partridge 1975, Butzer 1974, Butzer 1978). However, if silt and fine sand are dominant, as suggested by Brain (1958), then it follows that the only sedimentary structures that could possibly occur are ripple cross-lamination and flat beds (Harms *et al.*, 1975). Cross-bedding is restricted to sands with a grain size in excess of 0,1 mm and is distinguished from cross-lamination in terms of scale: cross-beds have a set height greater than 5 cm and a length greater than 60 cm (Allen 1968). Thus, most of the coarse sandy lenses are too small to generate megaripple bedforms and cross-bedding, and generally too coarse to generate ripple cross-lamination (Harms *et al.*, 1975). Furthermore the presence of silt and clay (Brain 1958: 110) implies that the original bed probably had well developed cohesive forces making it resistant to friction with the result that higher velocities than normal would have been necessary in order to move sediment and generate bedforms (Blatt *et al.*, 1972). Such currents would tend to leave a clear imprint in the geological record (Ager 1973).

SEDIMENTARY FACIES

One of the best sections for study occurs at Rodent Corner along the west face of the exit quarry (fig. 3). It should be stressed, however, that this section does not necessarily bear any relationship to other sections of so-called red muds and has been treated as a separate entity. At this site partially eroded travertine bosses and the cave wall appear to have constricted and localised the deposits (fig. 4) which make up a total thickness of about 1,9 m (fig. 5A). The base of the deposits is not seen, and the top is highly irregular. The deposits can be divided into two interbedded facies (fig. 6): (1) coarse sandstone; and (2) siltstone and fine sandstone which together form a depositional couplet generally bounded by mudcracked surfaces and up to 12 cm thick (figs. 5A and B).

Coarse Sandstone Facies

This facies is much paler in colour and drab compared to the siltstone and fine sandstone facies. It consists of lenses of coarse to very coarse sandstone with occasional granules composed predominantly of quartz, and as a general rule the coarser the sandstone the more disseminated the particles. Although the facies is usually sharply based and overlies a mudcracked surface (fig. 7), it contains no trace of rip-up mud clasts. Individual grains are markedly angular to subangular in character and generally associated with small bone fragments less than 1 cm long as a rule. The more elongate of these bone fragments show a distinct fabric with their long axes parallel or subparallel to bedding but without any obvious imbrication.

The concentration of coarse sand and occasional granules into sharply based, laterally persistent lenticular beds and their association with bone fragments showing a distinct fabric suggests that they were deposited under the influence of flowing water. However, despite the fact that they commonly overlie mudcracked surfaces, no rip-up mudclasts occur within the facies. Currents capable of moving such coarse-grained material must have had a velocity of between 40 and 100 cm/s (for flow depths of 1 m or less) (Blatt *et al.*, 1972). Velocities of this magnitude would normally be capable of eroding mudcracked surfaces unless the mud was wet and cohesive and therefore resistant to erosion. The absence of traction current structures such as ripple cross-lamination may be due to the coarse grain size, low granulometric contrast and rather dispersed nature of the grains in some of the sandstone beds. For example, with increasing grain size, ripples form over a progressively narrower range of flow velocities, and in sands coarser than 0,6 mm ripples no longer form (Harms *et al.*, 1975). The angular to subangular nature of the individual grains irrespective of composition points to a local source and short distance of transport.

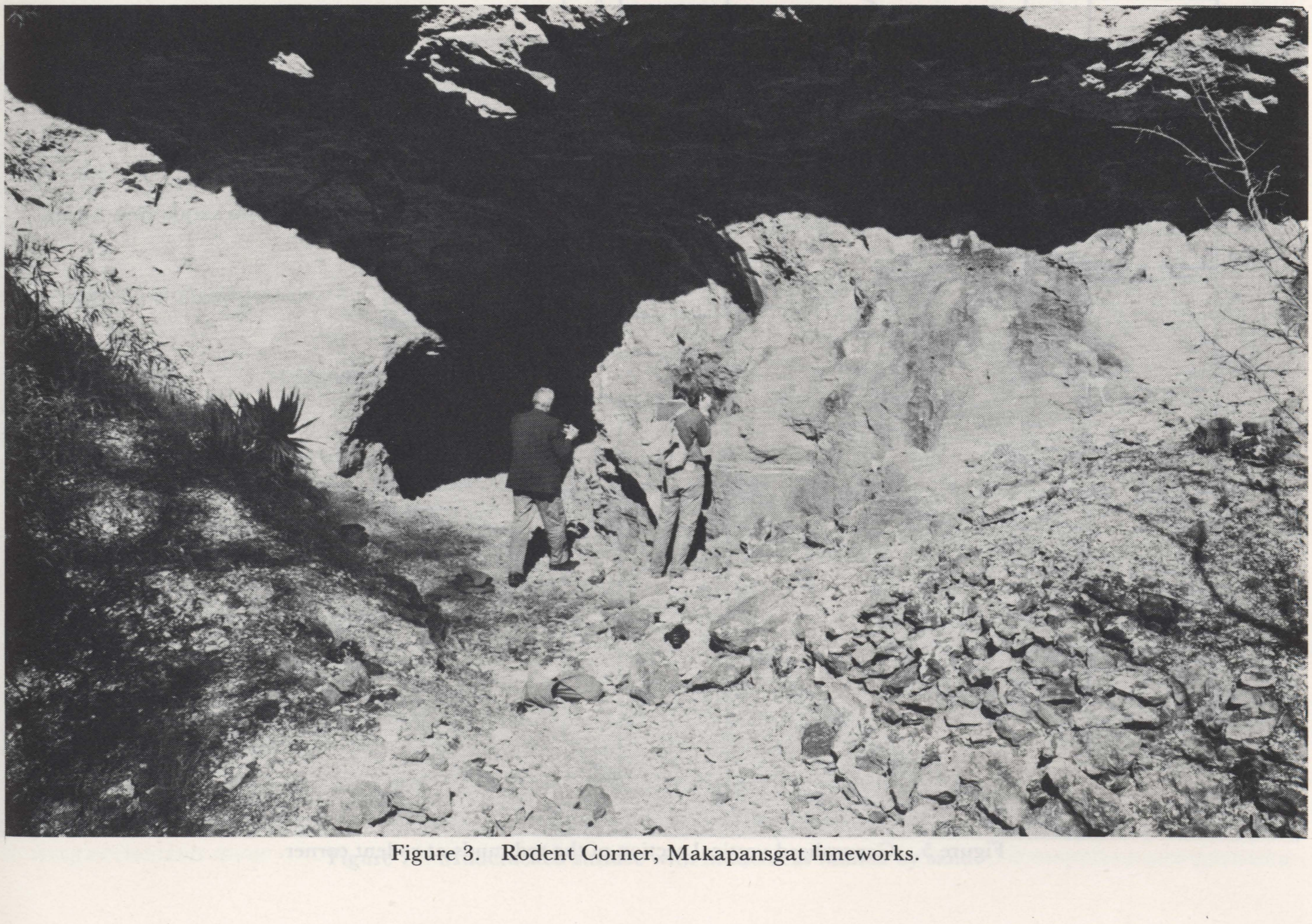

Figure 3. Rodent Corner, Makapansgat limeworks.

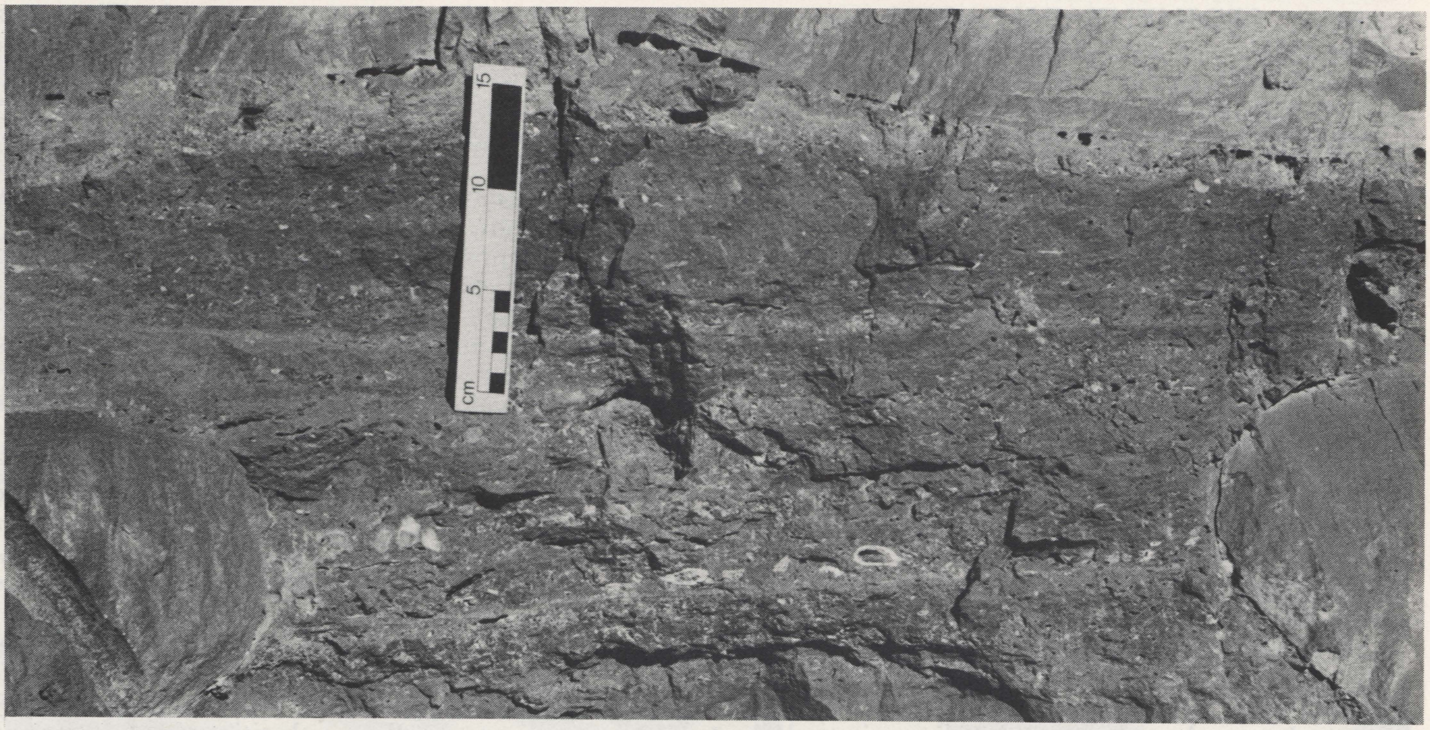

Figure 4. Red muds between partially eroded travertine bosses.

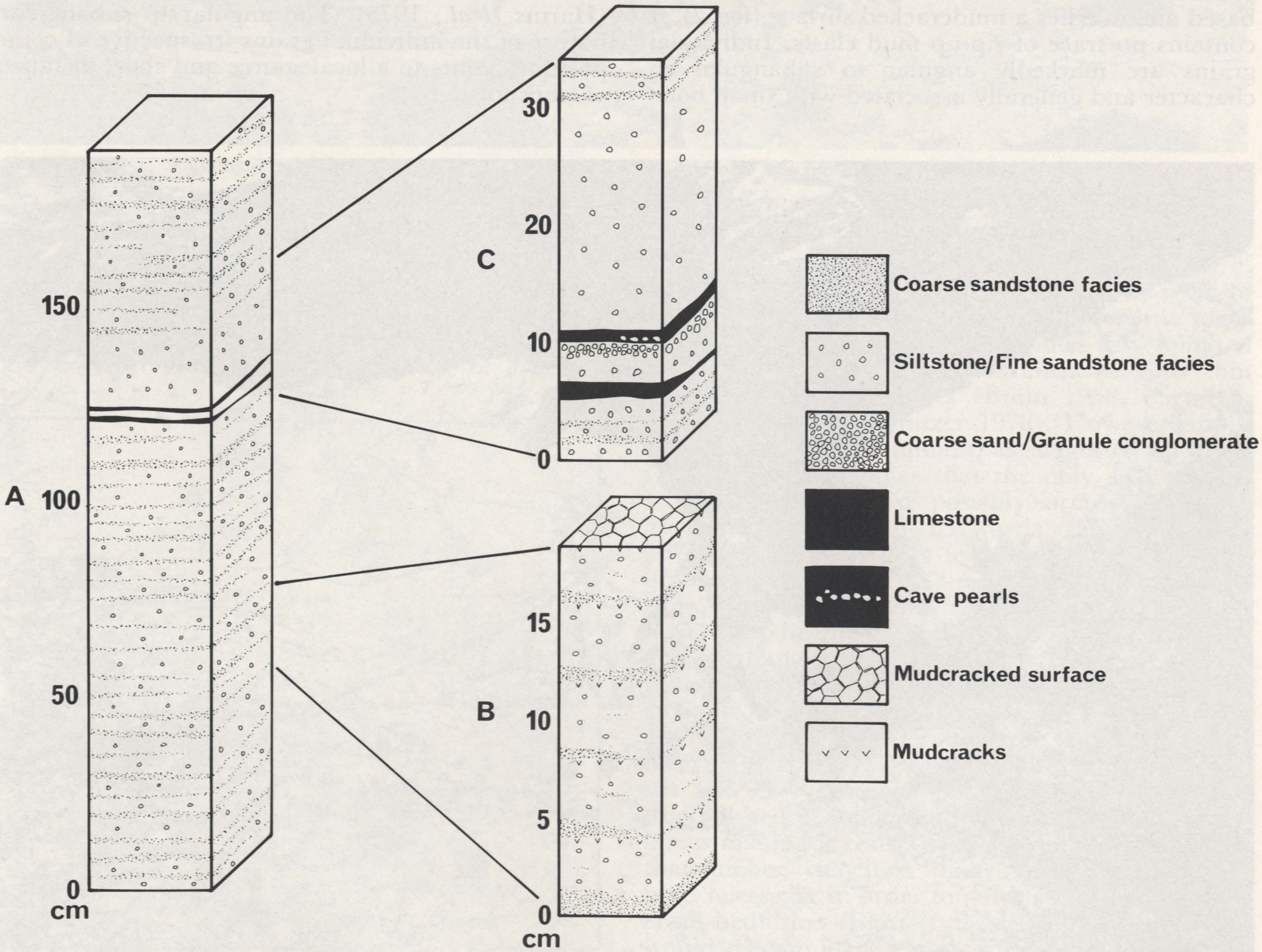

Figure 5. Generalised vertical section of the red muds at rodent corner.

Figure 6. Interbedded coarse sandstone and siltstone/fine sandstone facies. Scale in centimetres.

Figure 7. Mudcracked surface with mudcracks infilled by sand.

Siltstone and Fine Sandstone Facies

This facies tends to be slightly thicker on average (up to 5 cm) and laterally more persistent than the coarse sandstone facies (figs. 5B, 6). It is typically red and calcareous and contains angular to subangular, medium to coarse and very coarse sand grains disseminated throughout the facies or less commonly concentrated into fine lenses. Occasional bone fragments occur in this facies, some of them being much larger than those normally associated with the coarse sandstone facies. The top of the facies is usually deeper red in colour, slightly finer grained (clayey siltstone) and defined by a mudcracked surface with individual mudcracked polygons infilled by sand and occasionally impregnated with lime.

The absence of sedimentary structures of traction current origin, the finer grain size, lateral persistence and higher clay content of the siltstone and fine sandstone facies suggests deposition in slow-moving or standing water from quiet suspension sedimentation. Minor influxes of sediment are recorded in the fine sandy lenses but without any temporal or erosional break except at the top of the facies where there is usually a mudcracked surface and greater clay content and red colouration. This is attributed to shallowing of the water leaving behind a clay rich suspension layer which on exposure and drying formed a thin mudcracked surface. Shallowing of the water was probably due to changes in the level of the water table (Brain 1958) related to outside climatic factors. The coarse sand grains distributed throughout the facies resemble dropstones in glacial varves and may, as suggested by Brain (1958), have been derived mainly from insoluble residues from the dolomite.

The origin of the red colour of this facies is uncertain, although in modern sediments it is essentially a diagenetic process with the alteration of iron-rich minerals, especially clay minerals, producing a hematite coating to the grains. Berner (1969) has shown that hematite requires no special conditions to form diagenetically from iron hydroxides deposited along with the sediment even at low temperatures. A more important requirement than temperature is water, hence red colouration does not necessarily carry any inference about climate. Van Houten (1973) suggested a model in which coarse drab rock at the base of fluvial fining-upward sequences is overlain by finer grained red coloured sediments. The red colouration in such cases is attributed to the genetic association of high free iron abundance with high clay content. This model might be generally applicable to the facies couplets in that the red colouration is deeper at the top of the siltstone and fine sandstone facies where there is a higher concentration of clay minerals and where exposure of the depositional surface increased the oxygen potential. The idea that the red colouration was detrital in origin is unlikely insofar as recent sediments in moist climates, including those derived from soils such as that envisaged for the Makapansgat area at this time (Maguire pers. comm.), are not red but brown and yellow (Walker 1967, Van Houten 1973).

Facies Variation

About 1,2 m above the base of the succession a variation of the generalised facies pattern occurs (figs. 5C, 8). Here the normally interbedded depositional facies couplets are overlain by a thin (1,5 cm) white limestone layer which is in turn overlain by a bed of red calcareous siltstone and fine sandstone up to 3,5 cm thick containing occasional angular to subangular grains of coarse sand. Following this is a bed of disseminated coarse to very coarse sand grains capped by another white limestone layer about 1 cm thick which contains numerous cave pearls (0,1 to 3 cm in diameter). These pearls have a concentric structure which may be a growth pattern and are generally concentrated into localised pockets within the limestone layer (fig. 8). Above this limestone layer is about 20 cm of massive red calcareous siltstone and fine sandstone with angular to subangular coarse sand grains haphazardly disseminated throughout the rock. This is succeeded by the normally interbedded depositional facies couplet.

This anomalous sequence indicates a period of quiescence of sufficient time to allow for the precipitation of limestone followed by suspension sedimentation of silts and fine sands. The very coarse sand at the top of the suspension deposits is consistent with a major episode of current activity and the availability of larger than normal detrital grains for transport. Although there is a lack of directional structures, the lensing-out of this bed when traced a few metres to the east, the east-west orientation of the elongate bone fragments, and the overall slightly finer nature of the succession in this direction suggests the possibility of currents moving from west to east at this locality. The cave pearls with concentric structures may have originated within the lime-rich surface waters in locally agitated pools by concentration and precipitation about a central nucleus. The cave pearls have been compared to calcareous oolites by Partridge (1975) who suggested that they formed in shallow water around soil particles agitated by drip from the cave roof. The continuous oolitic rings around the particles leave little doubt that the particles were moving during their formation. The only doubt concerns the strength of the current, since modern oolites only occur where strong bottom currents exist (Blatt *et al.*, 1972). However, the association of the oolites with a limestone layer and their localisation within this layer implies quiet bottom conditions which were only locally agitated. The massive siltstone and fine sandstone above the limestone layer were deposited from suspension without interruption from flowing water and deposition of coarse sandstone beds. The coarser particles distributed throughout the bed were probably derived from insoluble residues from the dolomite.

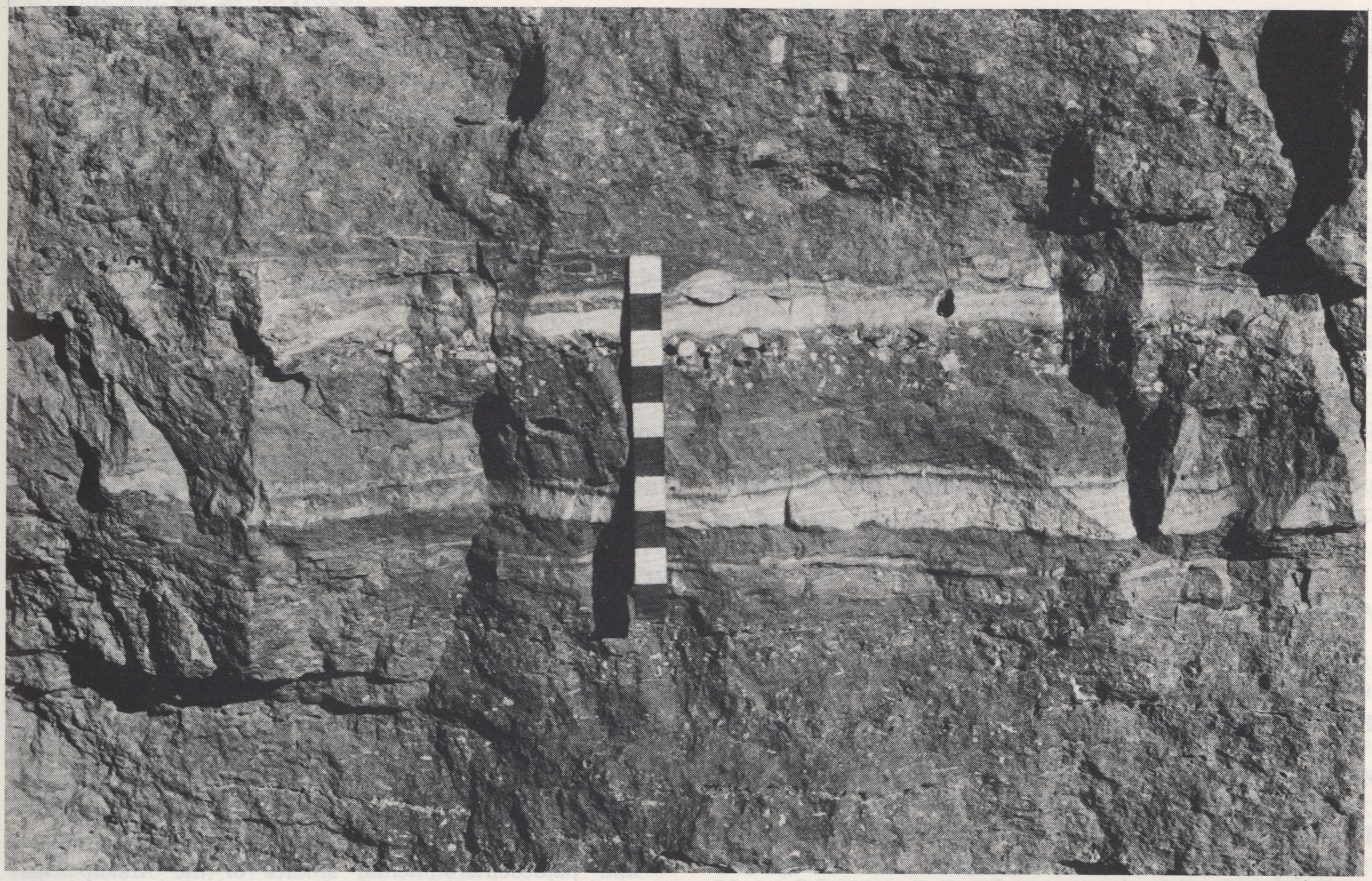

Figure 8. Limestone layers 1,2 m above base of succession, Rodent Corner. Note the coarse sand/granule conglomerate below upper limestone layer and the presence of cave pearls along the top of upper limestone layer. Scale in centimetres.

DEPOSITIONAL MODEL

Modern analogues of this facies couplet can be found on shallow marine shelves and in lakes where quiet suspension sedimentation of fines is periodically interrupted by deposition of storm sand layers (Reineck and Singh 1973). Similar depositional couplets of alluvial plain origin have been described from the Eocene Wasatch Formation, Wyoming, by Braunagel and Stanley (1977) who attributed them to rainy season floods with desiccation during dry periods. Thus the coarse sandstone facies is believed to be due to storm activity and heavy rainfall outside the cave washing coarse sandy detritus into the interior through what must at that time have been a very small opening. This also raised the level of the water table. The higher clay content and mudcracked surface at the top of the facies couplet (fining-upwards) suggests that it was probably deposited by a single depositional event.

In view of the lack of any regular pattern or relationship between depositional facies this was probably not an annual depositional event. The break in deposition between successive couplets indicated by the mudcracked surface could represent a considerable amount of time and could have varied between different couplets. This is confirmed by the existence of observable directional changes in magnetisation over similar distances to that of the depositional couplets, implying that the time scale of the couplets is significantly greater than one year. In terms of the palaeomagnetic dating of the deposits and their thickness the average depositional rate was about 10 cm per 3 000 years. Thus, for the depositional couplets to be interpreted as an annual event there would need to be such a gross deviation from the average depositional rate that the idea can be rejected (McFadden pers. comm.). Nevertheless, it follows that the thicker and laterally more persistent coarser grained sandstone beds are indicative of major storm events and were deposited much more rapidly than the interbedded siltstone and fine sandstone facies. If this interpretation is correct, then the coarse sandy beds provide clues to storm periodicity and rainfall. The only time that storm activity and rainfall waned occurred above the uppermost limestone layer when up to 20 cm of fine sand and silt was deposited without interruption.

Between storm episodes quiet suspension sedimentation occurred accompanied by a gradual shallowing of the water in the cave in response to a lowering of the water table. In many cases shallowing led to exposure of the depositional surface and the development of mudcracks, but because of the dampness of the cave, the mud never completely dried out. Storm activity and heavy rain outside the cave interrupted suspension sedimentation, raising the level of the water table in the cave above the depositional surface and washing in coarse sandy detritus. The clay rich layer at the top of the facies couplet would render it relatively impermeable to fluids percolating down when the next facies couplet was deposited.

The red muds at the Ancient Entrance to the cave differ from those at Rodent Corner in that they lack coarse sandy beds of external origin, they are much redder and they contain more bone material. They consist of siltstone and fine sandstone interbedded with irregular layers of limestone. These and mudcracked surfaces are more common and laterally more persistent in the lower part of the succession, which suggests a similar mode of origin possibly related to the upward expulsion of carbonate rich pore solutions following compaction.

The difference in character of the red muds at these two sites and the presence of externally derived sand layers at Rodent Corner implies that the two deposits were not connected and may have been separated by a floor high as shown by Maguire *et al.* (1980). Furthermore, any opening to the outside at this time must have been located close to Rodent Corner and not near the Ancient Entrance, assuming that the deposits are time correlatives.

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