INÍCIO E TÉRMINO DAS GLACIAÇÕES PALEOZÓICAS NO BRASIL

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BOULDER PAVEMENTS FROM THE ITARARÉ SUBGROUP (LATE PALEOZOIC) AT CAPIVARI, SP: NEW EVIDENCE ON ORIGIN*

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INTRODUCTION Rocha-Campos et al. (1976; 1977) initially described two well developed striated clast pavements cropping out in road cuts at km 36 of road SP-101, near the town of Capivari, State of São Paulo. The pavements, which appear as two extensive, linear, parallel, subhorizontal concentration of clasts, 2 m apart, were considered to be included within a single bed of silty-sandy diamictite (= intratill boulder pavements, sensu Dreimanis, 1989) from the middle part of the late Paleozoic Itararé Subgroup.

Analysis of characteristics and orientation of clasts from the pavements and from the enveloping diamictite by Rocha-Campos et al. (1976; 1977) showed that: a) the composition of clasts of each pavement roughly correlates with that of clasts of the diamictite unit immediately below it; b) parallel striae on the beveled upper surface of clasts are predominantly parallel to clast long axes in each pavement; average trends in the upper and lower pavements, however, differ substantially (NS and N281°, respectively); c) upper facets of pavement clasts are mostly inclined toward the south; d) though not strongly developed, the fabric of non-pavement stones is consistent with the orientation of striae on clasts in the pavement immediately below; and e) composition of the pavement clasts consists mostly of igneous and metamorphic lithologies and is consistent with the general diamictite provenance from the eastern Precambrian belt and with the regional ice-flow direction. The difficulties in fitting the features above into the models of origin of clast pavements then available (e.g. Flint, 1971; Dreimanis & Reavely 1953) were recognized by Rocha-Campos et al. (1976: 1977) who tentatively interpreted the formation of the structures through the concentration and modification of clasts along shear planes developed during deposition of a single basal till.

NEW DATA Re-investigation of the Capivari boulder pavements in the context of a comparative study of striated clast pavements from the late Paleozoic of the Paraná Basin and the Minnesota River Valley (Pleistocene). (Cotter et al., this Symposium.) yielded important additional evidence pertinent to a discussion of the origin of these peculiar sedimentary features. Results are summarized below.

Extent The known geographic extent of the two pavements has been expanded by detailed mapping (1:10,000) away from the two road cuts and now comprises an area of at least 5 km by 2 km. The structures are apparently horizontal and concordant with the regional dip of the late Paleozoic beds. Where better exposed the two pavements are remarkably parallel. Though usually associated with silty-sand diamictite similar to the one at the km 36 road cut, a possible exposure of the pavements was found intercalated within coarse, conglomeratic, feldspathic sandstone, some 3 km S of the above locality.

Clast characteristics and orientation Pavement clasts vary in size from pebbles to predominantly boulders (over 1.5 m in diameter). Clasts are rounded to subrounded and frequently bullet shaped. Large striated clasts with striae parallel to their long axes are numerous, but striae orientated transverse to long axes also occur. Excavation of the two pavements at one locality some 200 m NE of the cuts allowed areal examination of the structures. Clasts are here tightly packed. Many bullet-shaped clasts bear parallel striae on upper beveled surfaces, parallel to clast long axes. The attitudes of these surfaces are mostly subhorizontal, though some tilted and subvertical stones have been found.

Stratigraphy Contrary to the former interpretation (Rocha-Campos et al. 1976; 1977) several lines of evidence now indicate an intertillite rather than intratillite position of the two Capivari pavements. Most significant was the finding of relatively large, deformed (contorted) layers, lenses or irregular concentrations of silt and sand, within the diamictite below and alongside many of the pavement boulders. These intercalations terminate abruptly at the level of the upper beveled surfaces of clasts. Contacts of layers with the diamictite are irregular and seem erosional. Other features associated with the clasts are numerous fractures and reverse, low angle (shear) faults which displace the silt-sand layers. These features are also restricted to the zones below or around the clasts. Grain size analyses, however, showed that except for a discrete higher sand percentage in the middle layer, diamictite levels separated by the pavements have a similar silty-sandy composition (average 76,4% and 22,9%, respectively), with an insignificant percentage of clay.

DISCUSSION Critical to any hypothesis explaining the origin of glacially striated clast pavements is the determination of the processes involved in the concentration of clasts, either subglacially or pro-glacially. Clark (1991) and Hicock (1991) have recently reviewed models of origin of boulder pavements. The intertill position of the Capivari

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structures and the evidence of running (melt) water favours clast concentration by subaerial erosion of pre-existing sediments. The horizontal, relatively continuous and one stone thick nature of the structures suggest that concentration must have occurred over a wide area without much topographic variation. This topography was probably not too different from the present boulder pavement configuration. Concentration of clasts through subglacial fluvial erosion (Shaw & Ashley, 1988) would probally result in more discontinuous and topographicaly variable accumulations. Similarity of clast composition of pavement clasts with those from underlying diamictite bed is in agreement with the interpretation of clasts being concentrated from pre-existing till.

Formation of lag concentration was in each case succeeded by glacier overriding which remobilized, re-emplaced and abraded the clasts. Predominance of subhorizontal attitudes of clasts and concidence of parallel striae on upper beveled facets and long axes of clasts in the two pavements are consistent with subglacial planing of stones firmly held in the underlying diamict. The process of emplacement of the clast was probably similar to though not entirely coincident with subglacial lodgement (Boulton & Paul, 1976). From the nature and distribution of the deformation features it seems likely that clasts in the Capivari boulder pavements have been pressed down into the underlying till, perhaps plowing into the underlying bed only a short distance before becoming stuck. Displacement of silt/sand intercalations suggests that shearing occurred after clast concentration.

The proposed general model of origin of the Capivari pavements, therefore, broadly conforms with characteristics listed by Hicock (1991) for pavements resulting from lodgement/erosion as the dominant mechanism. The interpretation would imply multiple advances of the glacier with deposition of basal till alternating with episodes of retreat and erosion with the formation of lag concentrate. At present, however, it is not possible to exclude the possibility of local intervention or combination of other mechanims in the formation of the pavements (Hicock, 1991).

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THE ORIGIN OF STRIATED BOULDER PAVEMENTS: EVIDENCE FROM CAPIVARI, SÃO PAULO, BRAZIL (LATE PALEOZOIC) AND THE MINNESOTA RIVER VALLEY, USA (PLEISTOCENE)

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ABSTRACT Boulder or stone pavements are planar concentrations of clasts occurring within or between tills/tillites influenced and modified by glacial processes. A number of models have been presented to explain the origin of boulder pavements (e.g. Dreimanis & Reavely, 1953; Flint, 1955; Boulton & Paul, 1976; Eyles, 1988; Clark, 1991; Hicock, 1991), but the exact mechanisms are poorly understood. These models can be grouped into two categories: 1) subglacial-where clast concentration, deposition and modification occur through subglacial processes; and 2) clast concentrate overriding - the overriding and modification of a preexisting accumulation of clasts. In this latter model clast concentration can occur through winnowing, wave action, frost heave or glacio-fluvial erosion.

As these models indicate, the determination of the origin of boulder pavements has important implications for the understanding of glacial history, glacial flow characteristics and subglacial conditions.

Research on two distinctive and extensive boulder pavements, the late Paleozoic Capivari boulder pavements in the Paraná Basin, São Paulo, Brazil, and the late Pleistocene Minnesota River Valley boulder pavement of eastern South Dakota and western Minnesota, USA, reveals a great deal of similarity between these two deposits. Together they furnish additional evidence for the origin of boulder pavements.

THE BOULDER PAVEMENTS AT CAPIVARI Two extensive boulder pavements within the middle part of the