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Unravelling the depositional environment of the Archaean Rajkharsawan conglomerate (Jharkhand, eastern India)

A.J. van Loon[1,*], R. Mazumder[2,3] & S. De[3]

1 Geological Institute, Adam Mickiewicz University, Maków Polnych 16, 61-606 Poznań, Poland.
2 School of Biology, Earth and Environmental Sciences, University of New South Wales, Sydney 2052, Australia.
3 Geological Studies Unit, Indian Statistical Institute, 203 B.T. Road, Kolkata 700-108, India.
* Corresponding author. Email: tvanloon@amu.edu.pl.

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Abstract

Large conglomerate lenses occur in a fine-grained siliciclastic succession of the Singhbhum craton, eastern India. They overlie an Archaean orthogneiss, from which they are separated by a palaeosol. Neither the conglomerates nor the directly overlying rocks have been dated, but the conglomerate unit is assumed to have also an Archaean age. The conglomerate lenses occur within a succession of pelitic and mafic schists, and the depositional environment of this conglomerate/schist unit had not been clarified thus far. On the basis of a combination of the vertical and horizontal distribution of the conglomerates, their stratigraphic position and analysis of their sedimentological characteristics and the sedimentological context, it is concluded that the succession must have developed in a fluvial lowland environment where volcanic input contributed significantly to the sediment accumulation.

Keywords: Rajkharsawan conglomerate, eastern India, Archaean, fluvial environment, Singhbhum craton

Introduction

Several conglomerate bodies are exposed in the Rajkharsawan-Chakradharpur area (Sarkar, 1984), in the state of Jharkhand, eastern India (Fig. 1). The bodies occur within a unit of pelitic and mafic schists (upper greenschist to amphibolite facies) that overlies the so-called Chakradharpur Granite Gneiss (Bandyopadhyay, 1981), which has a Mesoarchaean age.

Previous studies

De (1957) was the first to investigate the Rajkharsawan conglomerates, but he did not interpret the sedimentary setting. He mentioned, however, some deformations of the conglomerate in the Rajkharsawan area. The clasts are flattened due to tectonic deformation (Fig. 2a), giving rise to pebble lineation. Our recent field work showed that some of the conglomerate also contain – locally strongly – folded clasts (Fig. 2b). It should be kept in mind, however, that the flattening and/or folding of the clasts depend on the clasts' position within the larger tectonic (fold) structures; almost unaffected (more or less equidimensional) clasts are therefore also present (Fig. 2c). The degree of deformation seems also to depend on the sorting: if the conglomerate is locally poorly sorted (Fig. 2d), the matrix seems to have absorbed part of the stress that otherwise might have have contributed to folding of the conglomerate as a whole, or of individual clasts.

Mazumder et al. (2000) suspected the conglomerate to be glacial, but comparison with well studied conglomeratic units from various Pleistocene glacial settings (e.g. Pisarska-Jamrozy et al., 2010; Salamon & Zielinski, 2010; Pisarski-Jamrozy and Börner, 2011) makes this interpretation untenable. The conglomerates and associated clastics also lack features that are characteristic of periglacial conditions (cf. Gullentops et al., 1981; Vandenberghe, 1992a,b; Vandenberghe et al., 2004; Vandenberghe and Czedek, 2008; Van Loon, 2009).

The problems in the reconstruction of the depositional environment of the conglomeratic succession (and of its

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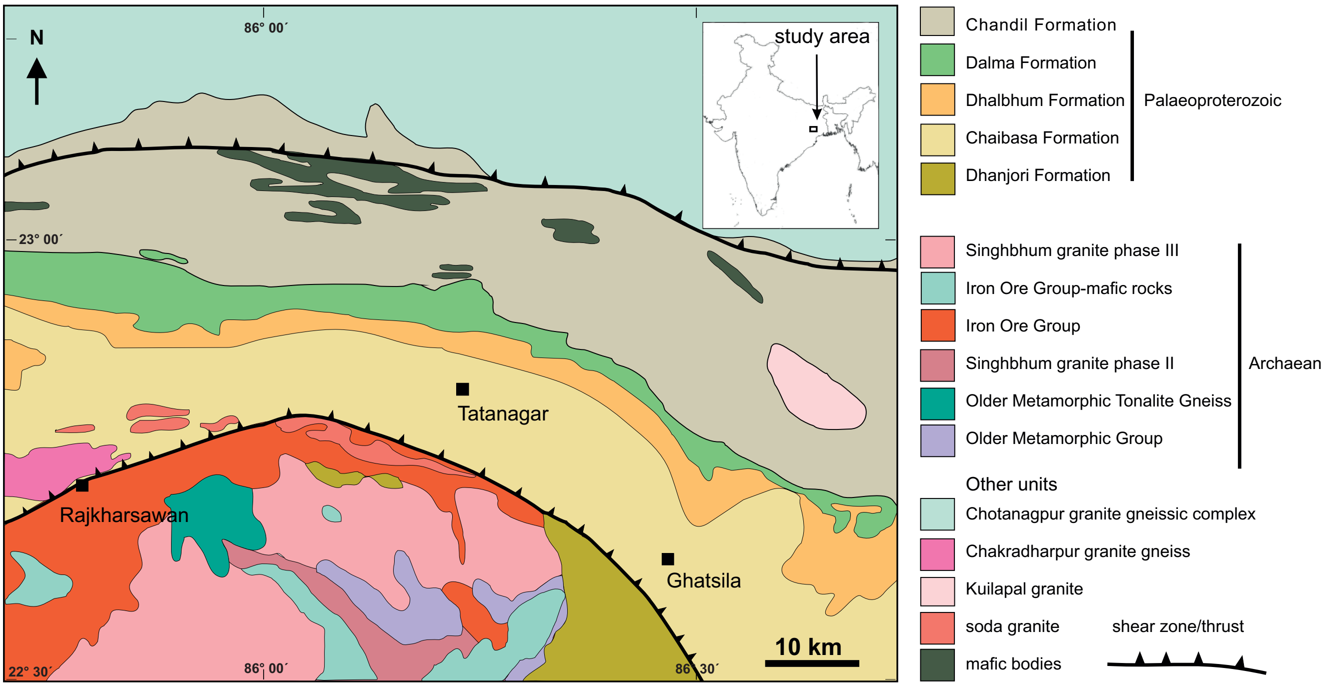

Fig. 1. Schematic, simplified geological map of the Singhbhum Basin (from Mazumder et al., 2012; after Saha, 1994, Sengupta et al., 2000, and Mukhopadhyay, 2001). Singhbhum Phase I Granites (Saha, 1994) are exposed only in the area south of this map. The extent of the Rajkharsawan conglomerates and schists (near the village of Rajkharsawan: left-hand side of figure, just North of the shear zone) is too small to be shown on this map.

further development) result, obviously, from the geological perspective, which makes any reconstruction or interpretation more difficult with increasing age of the rocks. Moreover, a genetic interpretation of the conglomerate/schist unit under study here is hampered because the schists in which the conglomerate lenses occur, have undergone strong tectonic deformation, as clear not only from the folds in the conglomerate itself (Fig. 3) but also from the folded pebbles that occur locally (Fig. 2b). For a reliable interpretation of the depositional environment, it is therefore necessary to analyse the geological context of the unit under study, as well as its relationships with the under- and overlying units, which are, however, tectonically deformed and metamorphosed as well. Therefore, the geological setting will be summarised first.

Geological setting

The Mesoarchaean-Palaeoproterozoic volcano-sedimentary succession of the Singhbhum craton, eastern India (Fig. 1), records sedimentation and volcanism in a changing tectonic setting (Eriksson et al., 1999; Mazumder et al., 2000; Mazumder, 2005). This early history of the area is important not only for an understanding of the Archaean evolution in India but also to trace its relationships with other crustal segments of India, Antarctica, North China, South Africa and Australia (Rogers, 1996; Eriksson et al., 1999; Mazumder et al., 2000; Mazumder, 2003; Zhao et al., 2003).

The Mesoarchaean succession in the Singhbhum area begins with the Iron Ore Group (IOG), characterised by banded iron formations (BIF), clastic sedimentary rocks and minor carbonates (Chakraborty and Majumder, 1986; Saha, 1994; Chakraborty, 1996; Mukhopadhyay et al., 2008). Several granites are also present; they must have intruded at different times, indicated as phases I-III. Saha et al. (1988) and Saha (1994) suggested that phase III of the Singhbhum granite is intrusive into the IOG rocks, whereas phases I and II formed the basement on which the IOG sedimentation took place.

In most of the Singhbhum supracrustal province, the Mesoarchaean is followed by a number of formations (from old to young the Dhanjori, Chaibasa, Dhalbhum, Dalma and Chandil Formations) that are partly volcanic, partly sedimentary in origin, but that all have undergone greenschist to amphibolite facies metamorphism (see Mazujmder et al., 2012 – and references therein – for an overview). As will be detailed below, only the lowermost of these formations (the Dhanjori Formation) may still partly have an Archaean age. The stratigraphic status of the Rajkharsawan conglomerate is still ambiguous, but recent fieldwork (2010-2011) provided evidence that the conglomerates are younger than the Iron Ore Group and the Singbhum III granite, but older that the Dhanjori Formation.

Stratigraphic setting

Mazumder et al. (2000) considered the Rajkharsawan conglomerates (these conglomerates have, as many more Indian rock units, not yet a formal name) tentatively as part of the Dhanjori Formation. It has now been found, however, that – unlike the Dhanjori basal conglomerate exposed in its type

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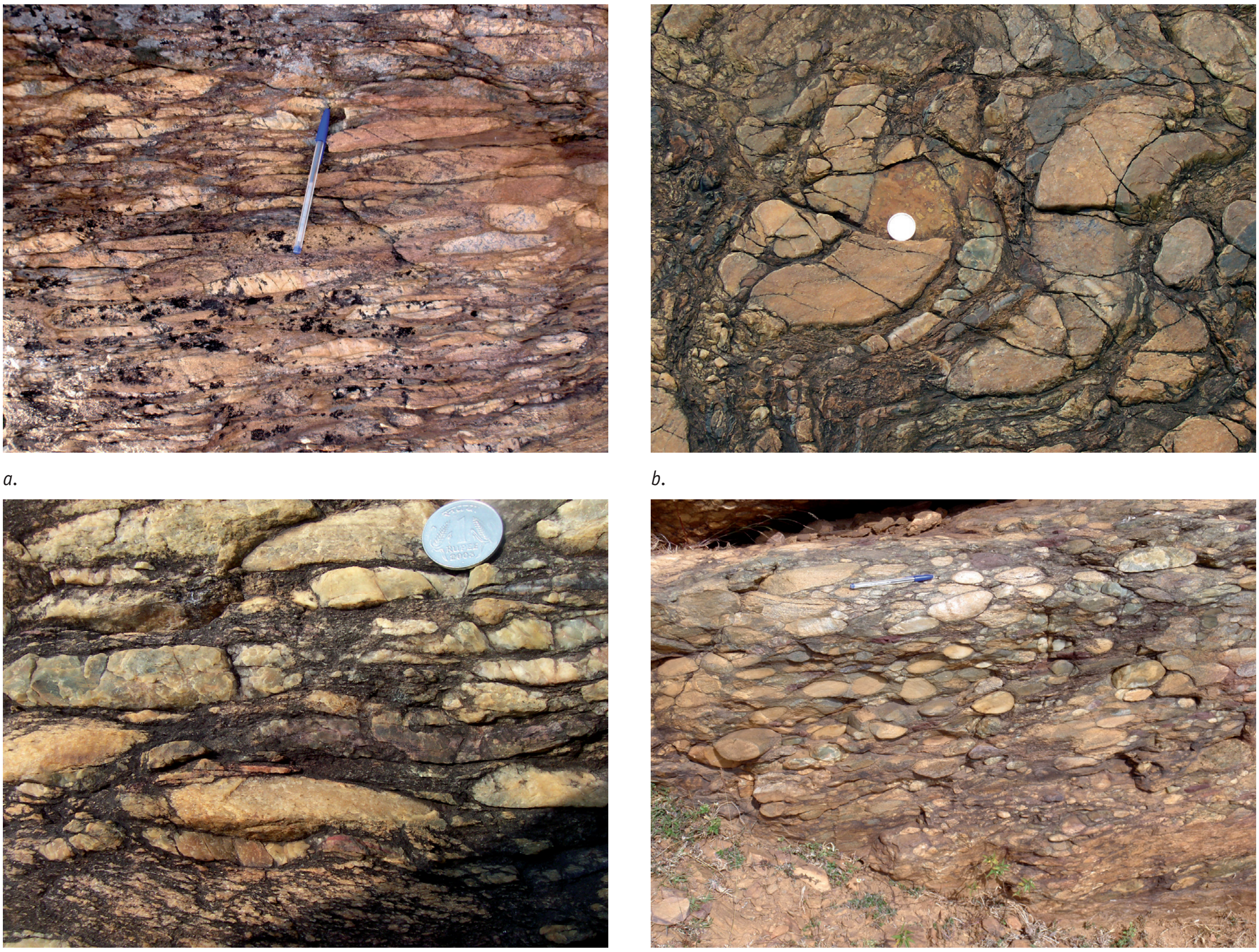

a. b.

c. d.

Fig. 2. Different aspects of the Rajkharsawan conglomerate. a. Well sorted part of a conglomerate with strongly flattened pebbles, almost exclusively consisting of quartzite; b. Folded pebbles; the blackish clasts are mainly schists, most pebbles are quartzites; c. Poorly sorted part of a conglomerate with slightly flattened pebbles; and d. Overturned top part of a conglomerate showing grading and only slightly flattened (partly equidimensional) pebbles.

area (the Singpura-Narwapahar area; see figures 2-4 in Mazumder & Sarkar, 2004), this conglomerate contains a small amount of BIF pebbles (Fig. 4) in addition to quartzite and slate pebbles. The presence of BIF pebbles proves that the conglomerates and associated rocks must be younger than the BIF of the IOG, whereas the lack of BIF pebbles in the Dhanjori basal conglomerate suggests that the BIF had already been covered by younger rocks when deposition of the Palaeoproterozoic or Neoarchean Dhanjori Formation started (Acharyya et al., 2010). The Rajkharsawan conglomerates thus seem to have an intermediate position, suggesting an Archaean age. For the time being, it remains unclear, however, whether this unit forms part of the Iron Ore Group, of another Neoarchaean complex, or of the volcano-sedimentary succession that started at the end of the Archaean and continued during the Palaeoproterozoic (see Mazumder et al., 2012). On the basis of the geographical position of the conglomerate/schist unit, it seems most likely that it forms part of the IOG.

Fig. 3. Intricately folded part of one of the conglomerate lenses.

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Fig. 4. BIF pebble in the Rajkharsawan conglomerate.

Sedimentological analysis of the Rajkharsawan conglomerate

The conglomerate bodies under study, which are embedded in schists (Fig. 5), mostly occur in and around the village of Udalkamn, south of the Rajkharsawan railway station (Fig. 6). They are mostly clast-supported (Fig. 2c) and form lenses that are up to some 250 m wide and up to some 10 m thick. The lenses do neither occur at the same stratigraphic level, nor exactly above each other, although their marginal parts may overlap (Fig. 7). The bases of the lenses are a bit irregular, but they have an overall bowl-like shape; whether the contact with the underlying schists is erosional, cannot be determined as no original structures have been preserved in these schists. The upper boundaries with the schists are dome-shaped; this shape of the upper boundaries is, however, most probably not a primary feature, but a result of differential compaction (the fine-grained schists must have undergone more compaction than the conglomerates in which hardly any compressible

Fig. 5. Parts of two conglomerate lenses within the schists.

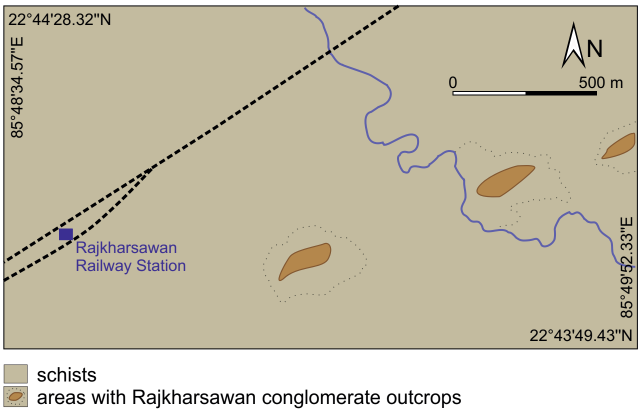

Fig. 6. Map of the study area.

material is present). The shapes of the lower and upper boundaries thus give the conglomerate units a lens shape.

In some places the conglomerates are poorly sorted (Fig. 2d) but considering the nature of the matrix it may well be that the matrix consists in these cases mostly of schist pebbles or cobbles that became crushed during tectonic deformation.

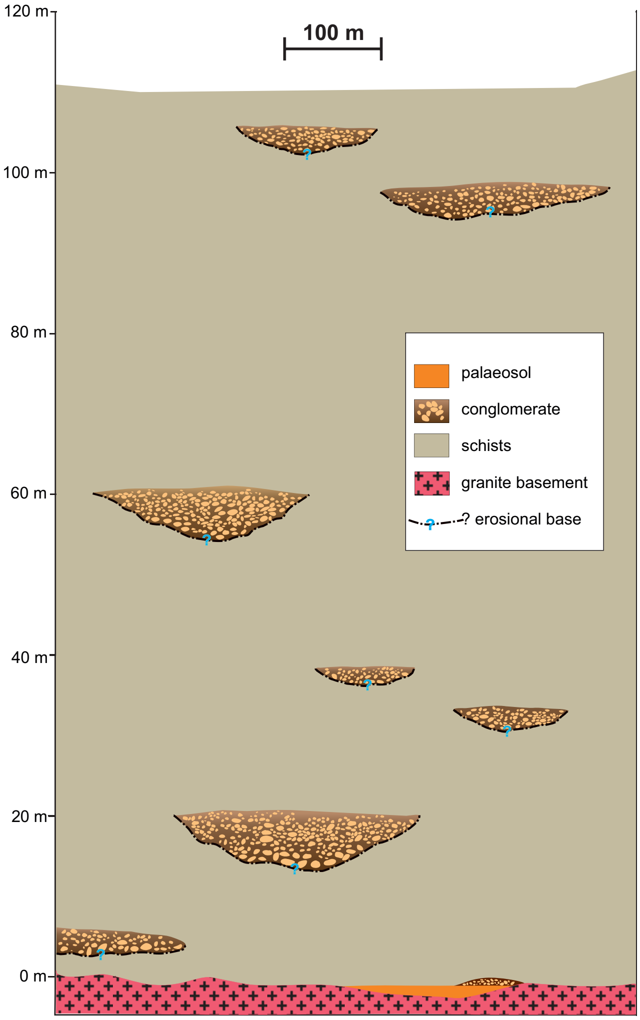

Fig. 7. Composite section of the Rajkharsawan conglomerates and schists near the Rajkharsawan railway station.

Most conglomerates, however, are, well sorted, particularly at their base. Many of the conglomerates tend in their upper parts to grade upwards into coarse- to medium-grained pebble-rich sandstones (Fig. 8). The conglomerate/sandstone units thus form fining-upward cycles (see also Fig.7).

Fig. 8. Top part of one of the conglomerate units, consisting of a pebbly sandstone.

The pebbles consist for the great majority (>95%) of quartzites, with a minor amount of schists and rare BIF pebbles. Due to flattening (and locally folding) of the pebbles, their original shapes cannot be reconstructed with accuracy, but almost all pebbles are well rounded, with minor amounts of sub-rounded pebbles. The sizes of the pebbles vary from place to place, both vertically and laterally, but numerous pebbles have a longest axis of over 20 cm; taking into account that flattening may have increased the length of the a-axis, and presuming that the average ratio between the longest and the shortest axis was about 2:1 (which is a common value for many conglomerates), the original length of most clasts must have been at least some 10 cm.

The conglomerate lenses must have undergone strong tectonic stress, as shown by the presence of folded pebbles (Fig. 2b). Whereas at many places the pebbles in the conglomerates show layer-parallel lengthening (see Fig. 2a), the folding of the pebbles at this site indicates that the main pressure responsible for their folding must have been roughly perpendicular to the original bedding plane; later deformational events have complicated the internal structure of the conglomerate (Fig. 3). This implies that the lenses now may be wider and thinner than they were immediately after their accumulation. Considering the most likely degree of vertical flattening of the pebbles, and taking into account the fact that the original conglomerates may have been less densely packed, the conglomerates may originally have been roughly twice as thick (some 5-20 m on average) as they are nowadays, and that they had an average original lateral extent of some 25-100 m, being 50-75% of their present-day width.

It is impossible to obtain more accurate deformation data from the schists that surround the conglomerates. These schists consist largely of volcanoclastic material; it is well possible that a significant amount of non-volcanoclastic material was originally present, but this is not well traceable anymore due to the metamorphism. Any sign of possible tectonic deformation has also been overprinted by the metamorphism.

Genetic interpretation

The fact that a glacial origin of the conglomerates, as speculated by Mazumder et al. (2000), is not tenable (no glacial striae, no diamictic horizons, no glaciation-related facies transitions), makes it only more challenging to interpret the depositional environment of the conglomerates and associated schists. Lenses of conglomerates within fine-grained material can reflect a wide range of depositional processes and environments, ranging from deep-sea (e.g. glaciomarine) to upland areas (e.g. mountainous alluvial fans). The grading that they commonly show limits the possibilities, as (normal) grading can represent only a limited number of processes: settling from suspension, waning currents, and – in specific cases – mass transport.

Settling from suspension can be excluded considering the size of the clasts. Mass transport is highly unlikely (although it cannot be fully excluded for some of the conglomerate lenses) considering the well rounded character of almost all clasts, the high width/height ratio of the lenses, and their lateral and vertical distribution. More important, however, is that mass flows capable of transporting decimetre-sized clasts can develop only if a sufficient – relatively large – amount of fine-grained material is present. Both field and microscopic data show, however, that at most places hardly any fine-grained material is present in the conglomerates. This leaves waning currents as the only likely depositional process.

Such currents can occur in several environments. Fossils cannot help to identify the environment, as very little is known about Archaean life forms, and because the Archaean micro-organisms – if ever present in these rocks – would have left no visible traces after metamorphism; in addition, there are no indications thus far that some life forms had conquered the continents already in the Archaean or Palaeoproterozoic. The environmental interpretation of the currents must thus be based on the lithofacies and lithofacies distribution only, as no recognisable primary structures have been preserved.

Important in this context is the association with fine-grained sediments. In combination with the graded character of some of the conglomerates, this limits the possible sedimentary environments; only mass flows (either or not marine) and deposition by a meandering river (with the conglomerates as channel fills and the schists as alluvial-plain sediments) fit

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well in this picture. Mass flows can, however, as detailed above, be excluded. Therefore the conglomerate/schist unit probably represents a meandering fluvial deposit: the conglomerates represent the channel fills and the fine-grained sediments represent the overbank deposits. This explains also the lens shape of the conglomerates with dome-shaped upper boundaries: the differential compaction (stronger compaction of the fine-grained schists) resulted in relief inversion, just like visible in present-day landscapes where sand-filled channels are exposed at the surface in the middle of fine-grained (fluvial or shallow-marine) sediments.

The entirely or largely volcaniclastic character of the fine-grained deposits can be explained by either ongoing volcanic activity during deposition, resulting in the accumulation of a thick succession of fine-grained volcanic ashes along the meandering river (obviously, the ashes will also have fallen in the river, but the high energy level prevented deposition), or by erosion in the upstream part of volcanic ashes that had been deposited there, were carried along by the river, and deposited on the alluvial plain that became flooded during high-discharge phases.

Discussion

During its long geological history, the Rajkharsawan clastics have undergone multiple deformational events, as well as various phases of metamorphism. These have obliterated many of the primary characteristics of the succession. Moreover, only a few – relatively small – areas have been left where they can be studied. This implies that any reconstruction of the depositional environment must be based on less data than are available for most younger sediments, and, consequently, that the environmental interpretation leaves space for discussion. On the other hand, all characteristics that are still observable, fit in the interpretation of a fluvial environment, and no other depositional environment can explain all the observable characteristics satisfactorily.

Strong support for the fluvial environment comes, however, from the stratigraphical and sedimentological context. The unit is developed on top of a palaeosol (Fig. 9) which indicates a terrestrial environment before deposition started. It is therefore likely that a hiatus exists between the formation of the palaeosol and the deposition of the Rajkharsawan sediments (but there is no definite proof). This implies that the area was exposed subaerially. Continental deposits (such as fluvial ones) on top of the palaeosol are therefore more likely than marine deposits. If, however, the area would have become submerged due to a transgression, the palaeosol would most probably have been eroded away, and a basal conglomerate would likely have formed. The conglomerates do, however, not show any of the characteristics of a transgressive lag deposit (a more or less continuous band; pebbles and cobbles consisting mainly of the underlying material – here the granitic gneiss directly under the palaeosol). It is therefore much more likely that the source area of the conglomerate clasts was somewhere in the hinterland, where local tectonics may have led to upheaval that resulted in erosion. The presence of clasts with different lithologies (schist and BIF pebbles in addition to the dominating quartzite pebbles) is also an indication of a remote source area. During the long transport (well rounded pebbles) the river apparently eroded several lithological units.

Fig. 9. The palaeosol underlying the unit with the Rajkharsawan conglomerates and schists. One conglomerate unit has been found immediately on top of the palaeosol; elsewhere the schists overly the palaeosol.

Additional evidence for this hypothesis is that, at a distance of roughly 50 km to the East, the Dhanjori Formation of probably Neoarchaean to Palaeoproterozoic age was formed, which is, according to the current knowledge, somewhat younger than the Raikharsawan clastics. The basal part of the Dhanjori Formation, with its angular clasts, is interpreted as an alluvial fan, and thus also represents a continental deposit (also with volcanoclastics) (see Mazumder & Sharkar, 2004; Mazumder, 2005).

Conclusions

The Rajkharsawan succession in Jharkhand, eastern India, post-dates a Mesoarchean orthogneiss, but predates the Neoarchaean to Palaeoproterozoic Dhanjori Formation, the lower part of which represents an alluvial fan. The Rajkharsawan succession is interpreted as a fluvial deposit, consisting of channel deposits represented by conglomeratic lenses, and of alluvial-plain deposits, represented by schists of largely fine-grained volcanoclastic material. The genetic relationship with the nearby Dhanjori Formation suggests that the Rajkharsawan conglomerate is not much older, suggesting a Neoarchaean age.

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