Large Igneous Provinces, Mantle Plumes and Uplift: A Sedimentological Perspective

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Significant pre-volcanic uplift of the lithosphere is one expected consequences of mantle plume upwelling (Campbell & Griffiths, 1990; Farnetani & Richards, 1994). Many major mafic/ultramafic lavas have been attributed to plumes that are expected to produce crustal uplift preceding the major phase of volcanism. Such pre-volcanic uplift would significantly affect regional sedimentation pattern, including:

1. progressive palaeogeographic shallowing and thinning of strata,
2. the abrupt appearance of erosional unconformities ("sequence boundaries" in sequence stratigraphic terminology), and
3. radial drainage and palaeocurrent patterns.

Subsequent erosion may remove much of the volcano-sedimentary record of domal uplift. However, sedimentologists can identify progressive shallowing of palaeogeography prior to volcanism and distinctive palaeocurrent patterns if these exist, and this may provide constraints on plume interpretations of the volcanic episode.

LIP - MANTLE PLUME CONNECTION

LIPs may or may not be related to mantle plumes. It is difficult to defend a LIP-mantle plume connection where pre-volcanic lithospheric uplift is absent. This is particularly true for continental flood basalts (CFB; Czamanske et al., 1998; Sheth, 1999). Also, not all oceanic LIPs are associated with pre-volcanic crustal uplift (e.g., Neal et al., 1997).

An important question related to plume models for LIPs is whether uplift and extensional deformation precede magmatism in the manner predicted by experimental and numerical models (Griffiths & Campbell, 1991; Farnetani & Richards, 1994; He et al., 2003).

SEDIMENTOLOGICAL INSIGHTS

The sedimentological and stratigraphic criteria proposed for tracing LIP-plume connections are somewhat generalized, and will not all be useful at a given location. For example, progressive shallowing of palaeogeography as a consequence of plume-induced lithospheric uplift should be clear in a marine depositional setting (e.g., in the transition from deep to shallow marine, or marine to terrestrial palaeogeography).

LATE PALAEOPROTEROZOIC DHANJORI FORMATION, INDIA: A CASE STUDY

There is a strong correlation between CFB provinces and cratonic margins (Anderson, 1994; King & Anderson, 1995). Also a majority of CFBs have apparently erupted through deep rifts containing thick sedimentary sequences (e.g., Sheth, 1999). Best studied are Phanerozoic CFB, although mantle plumes have been invoked to explain Precambrian mafic volcanism as well.

The Late Palaeoproterozoic siliciclastic Dhanjori Formation, Singhbhum province, India (Figs. 1,2) comprises terrestrial (alluvial fan-fluvial) continental deposits along with interbedded mafic and ultramafic (minor felsic) magmatic rocks formed in an intracontinental rift setting (Mazumder & Sarkar, 2004). The magmatic episode is unrelated to normal plate boundary processes (Mazumder & Sarkar, 2004) and thus the magmatic component of the Dhanjori Formation represents a LIP (Coffin & Eldholm, 1994; Prokoph et al., 2004).

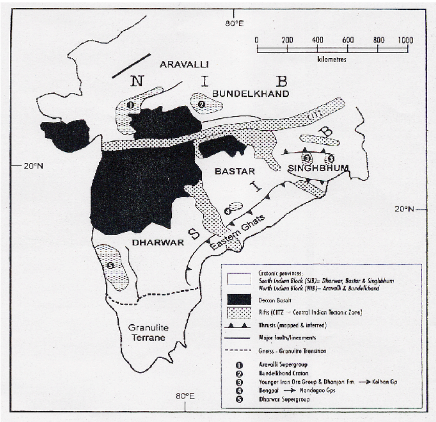
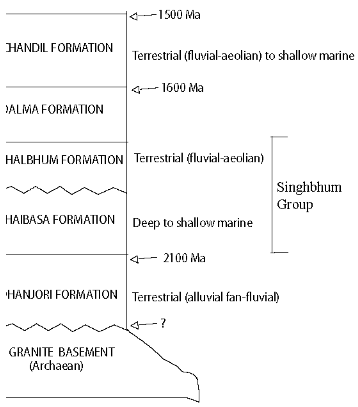


Figure 1: Simplified map showing disposition of major Precambrian crustal provinces of India (after Eriksson et al., 1999).



igure 2a. Revised Proterozoic tratigraphic succession of the inghbhum crustal Province

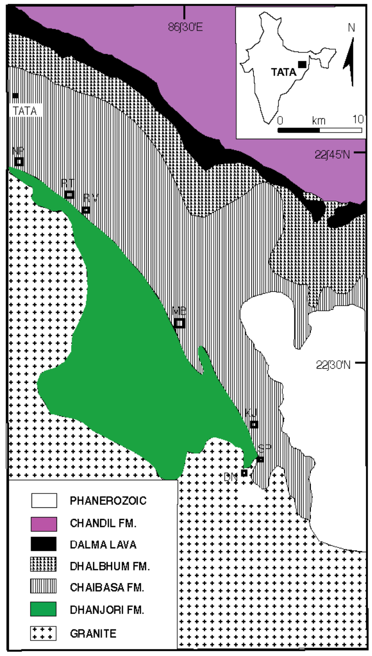


Figure 2b. Simplified geological map of the Dhanjori basin study locations: DN, Dongadaha; KJ, Khejurdari; SP, Singpura; MB, Mosaboni; RM, Rakha Mines; RK, Rukmini Temple (Jadugorah); NP, Narwa Pahar.

The Dhanjori Formation overlies Archaean Singhbhum Granite (Fig. 2a) and is overlain by the deep-to-shallow marine Chaibasa Formation (Bose et al., 1997; Figs. 2a,b).

The Dhanjori Formation comprises two members: the lower member includes phyllites, quartzites and thin conglomerates, whereas the upper member has volcanic and volcaniclastic rocks along with some quartzites and phyllites (Figure 3).

Basin tilting and volcanic eruption intervened and resulted in the second phase of Dhanjori sedimentation, although the general fluvial depositional setting remained unaltered. The different palaeocurrent trends displayed by the two members are a consequence of fluvial response to basin tilting (Fig. 3; Mazumder and Sarkar, 2004).

Dhanjori volcanism took place in an intracontinental rift setting as is evident from the interbedded, compositionally immature terrestrial deposits (Mazumder & Sarkar, 2004; Figs. 4a,b). Confinement of the volcanic and volcaniclastic rocks within the upper member (Fig. 3) implies that initiation of rifting was not a consequence of convective upwelling in the mantle. The presence of basalts (Figure 5), including some ultramafics, within the upper member implies subsequent upwelling of mantle materials and decompressional melting following crustal extension.

Although earlier workers reported komatiitic rocks from the Dhanjori basin, typical komatiites with convincing chemistry and texture are absent. Although interbedded volcanics and volcaniclastics at different stratigraphic levels within the upper member indicate episodic volcanic eruption during sedimentation, evidence for pre-volcanic uplift are lacking and so is a radial palaeocurrent pattern (Cox, 1989; Kent, 1991).

If Dhanjori volcanism is related to a mantle plume, then the consequences of this plume are not seen in the sedimentological record. Alternatively, the volcanism may simply represent a CFB unrelated to a mantle plume.

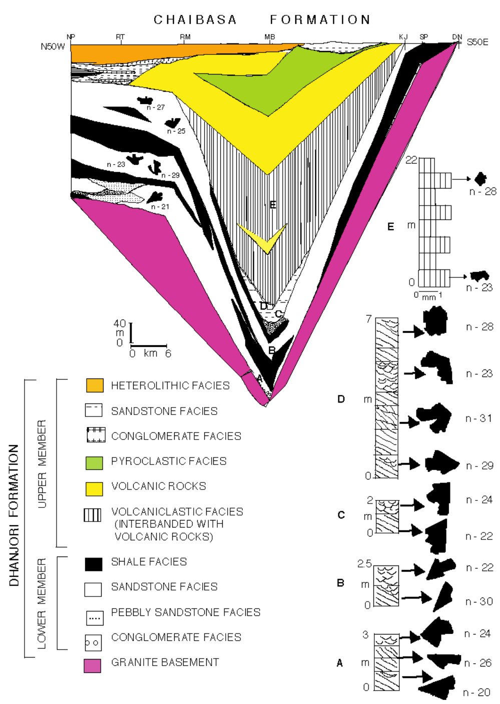
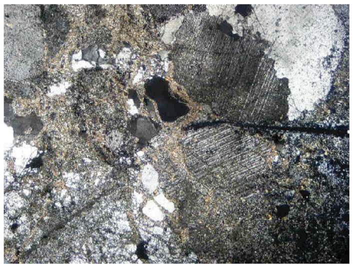


Figure 3. Panel diagram showing lateral and vertical facies transition during Dhanjori sedimentation



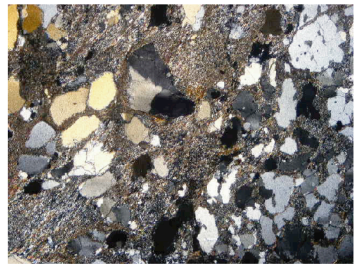


Figure 4. Compositionally (a) and texturally (b) immature Dhanjori sandstones (wacke;bar length 2mm)

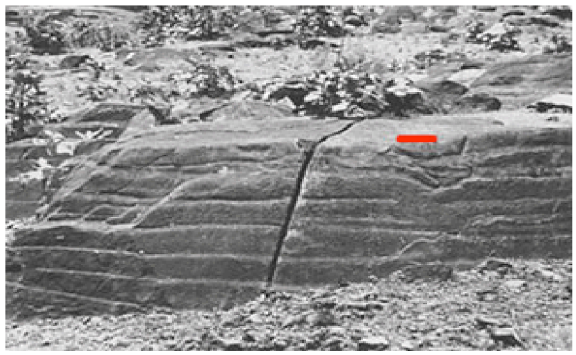


Figure 5. Dhanjori basalt showing excellent flow banding.

CONCLUSION:

The claim that the sedimentary record provides independent supporting evidence for mantle plume influence on the generation of LIPs, is not always true. The genetic linkage between CFBs and mantle plumes is at best difficult to establish from sedimentological analysis alone.

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