The Siwalik Molasse: A Sedimentary Record of Orogeny

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Abstract: The Siwalik molasse basin lies on the southern margin of the Himalayan orogenic belt. Continuously exposed from the Sulaiman Range in western Pakistan to Assam in the eastern India, the Siwalik sediments consist of over 7000 meters of fluvial sediments ranging in age from late Miocene to Pleistocene.

The continuation of the mountain building activity which first uplifted the source area to the north, is now responsible for the deformation and hence exposure of these sediments. This deformation characteristically diminishes in intensity southwards from a boundary thrust fault to the undisturbed Indo-Pakistan shield.

The Siwalik sediments have been extensively studied — initially because of their excellent record of late Tertiary mammalian evolution, and more recently, because of their record of source area unroofing and changing sedimentary environments.

INTRODUCTION

The Siwalik molasse basin lies on the southern margin of the Himalayan orogenic belt. Continuously exposed from the Sulaiman range in Western Pakistan to the Assam area of eastern India, the Siwalik Group comprises over 7000 meters of fluvial sediments ranging in age from Miocene to Pleistocene.

The continuing mountain building activity which first uplifted the source area to the north is now responsible for the deformation and hence exposure of these sediments. This deformation characteristically diminishes in intensity southwards from a boundary fault to the undisturbed Indo-Pakistan shield. The uplifting Himalaya continues to provide a source for the modern rivers of the Indo-Gangetic Plain which are in the process of depositing molasse at this moment.

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NOMENCLATURE BACKGROUND

Early workers subdivided the Siwalik molasse sequence into a number of faunal and facies based classification schemes. The most widely used set of subdivisions is based on a series of type sections scattered principally across the Potwar Plateau. Considerable effort has been expended to force the Siwaliks of Pakistan and India to fit these nomenclature schemes.

Unfortunately, the nature of fluvial sediments is such that rapid facies changes are common and reflect individual vagaries of the depositing river systems. Thus efforts to map facies changes across the Siwalik basin have resulted in confusion and frustration. Furthermore efforts to devise and then map faunal zones have proven of less than widespread value due to the erratic occurrence of well preserved fossil material, as well as the occasional intermingling of faunas of more than one age by depositional processes such as the redeposition of fossiliferous lag gravels.

Clearly a novel and more objective scheme is called for. Such a tool is provided by paleomagnetism.

This paper describes one aspect of lithofacies analysis made possible by the interpretation of paleomagnetic studies from the flanks of folds in the eastern portion of the Potwar Plateau (figure 1).

PALEOMAGNETIC STRATIGRAPHY

Previous studies have shown that the earth's magnetic field has exhibited a random pattern of polarity reversals over time. This pattern has been well dated by radiometric studies of terrestrial lava flows (see for example Mankinen and Dalrymple 1979). Studies have shown that this reversal sequence is preserved in the calm water deposits of the Siwaliks (for example Opdyke et al 1979). The interpretation is that slack water deposits settle sufficiently slowly so that the magnetic components are imparted a prefered orientation by the earth's magnetic field. Successive layers of siltstone then preserve the history of the earth's magnetic field.

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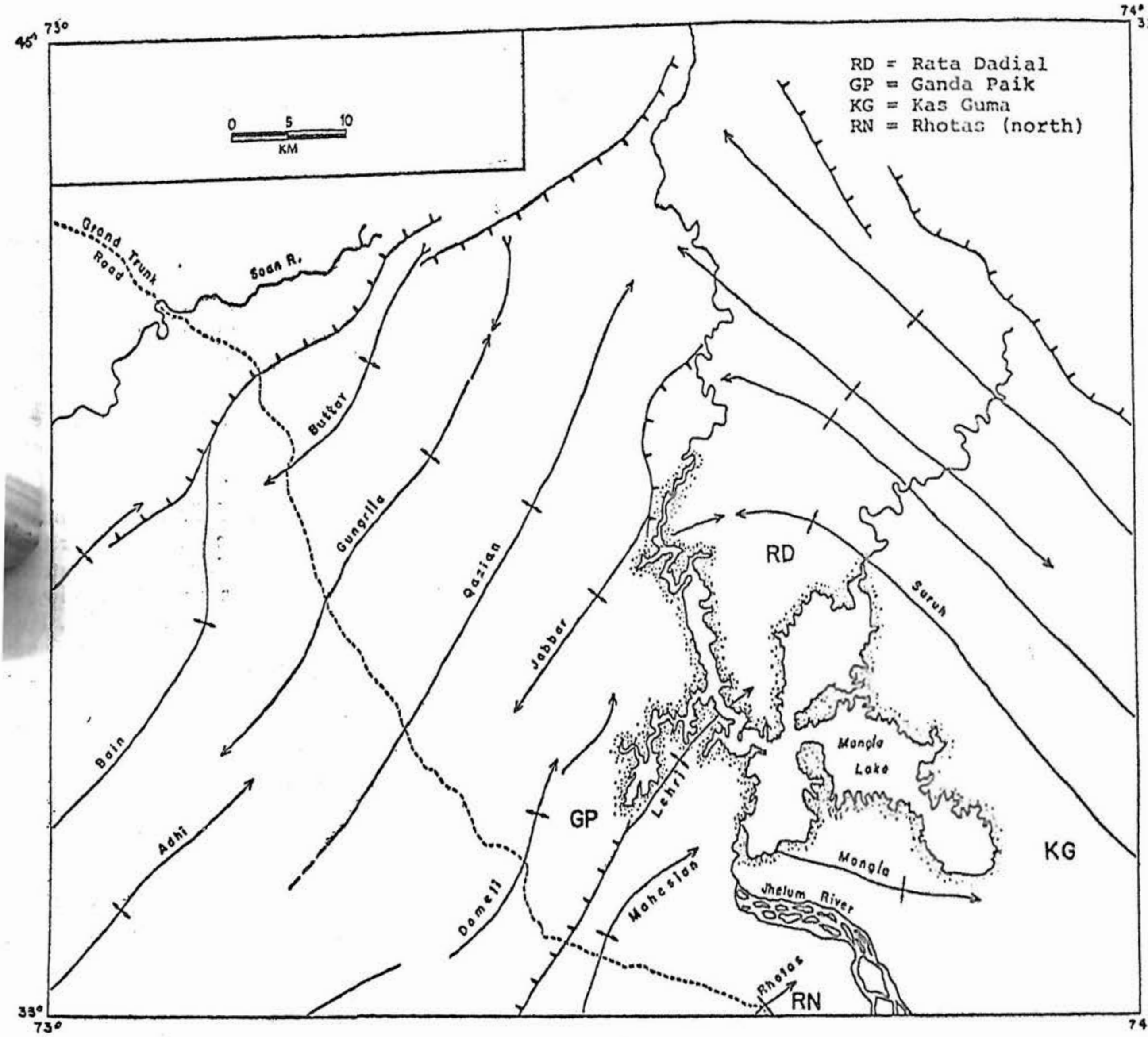

Fig. 1. Structures of the Eastern Potwar with Section Locations.

Extensive sampling programs have allowed entire stratigraphic columns to be accurately dated over much of the Potwar area, and there emerges a new ability to create maps of isochrons or time lines. This research is being carried out in a joint effort between Peshawar University, Dartmouth College, and Lamont Doherty Geological Observatory (see for example Johnson et al 1979 and Opdyke et al 1979). Figure 2 shows an example of a dated stratigraphic column from near the village of Ganda Paik located east of Sohawa. The interpretation of the paleomagnetic pattern of this section is supported by the occurence of volcanic ashes which have been dated by radiometric techniques and shown to cluster in the environs of 2.4 m.y. (G.D. Johnson et al, in preparation).

APPLICATION TO TECTONICS

Analysis of dated rock columns allows us to infer the history of deformation of the molasse sequence of the eastern Potwar Plateau. Long stratigraphic sections have been dated from over ten anticlinal structures. Minimum ages of uplift are derived by dating the youngest conformable river sandstone crossing the structural axes. Our interpretation is based on the premise that the structure had no surface expression at the time that the sand was deposited across the future fold axis. Further evidence for the onset of deformation is provided by the occurrence of abrupt facies changes such as the sudden influx of coarse materials derived from the erosion of Siwalik sediments from

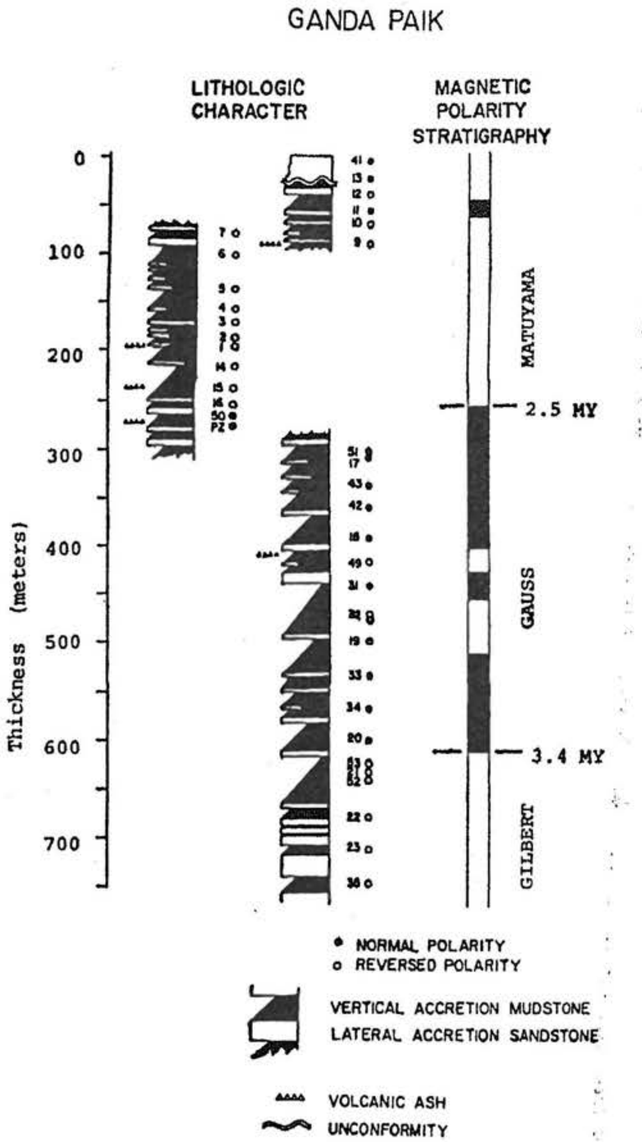

Fig. 2 Paleomagnetic stratigraphy at Ganda Paik. Location of section is identified by GP on figure 1.

nearby growing structures. The proximity of the source of the clasts is emphasized by the poorly consolidated nature of these Siwalik pebbles.

These studies reveal that the deformation of the eastern Potwar Plateau is a very recent event. Most of the structures comprising this extensively folded terrain have attained significant surface expression within only the past 2 million years. Structures in the Jhelum area, such as the Rhotas and Pabbi anticlines are particularly youthful, with deformation beginning less than 700,000 year ago (Opdyke et al, 1979).

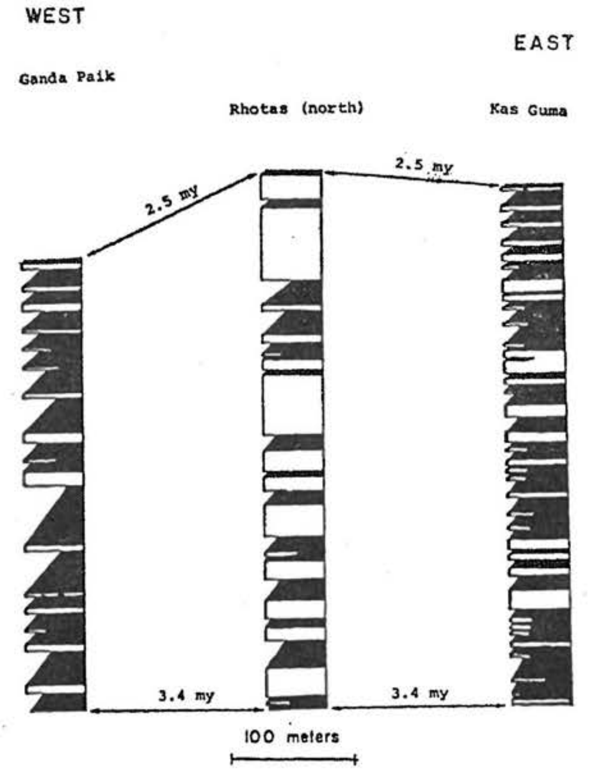

Fig. 3 Example of facies change due to river channel concentration. Each section spans all of Gauss magnetic epoch. Note predominance of mudstones (black) in the lateral sections while the axial section at Rhotas is characterized by thick sands (white). The section locations are shown on figure 1, and are each separated by 25 km.

APPLICATION TO DEPOSITIONAL ENVIRONMENTS

The dating of adjacent stratigraphic columns allows us to see a three-dimensional picture of paleogeographic conditions. Studies demonstrate pronounced facies changes in both lateral (spatial) and vertical (temporal) senses.

In one case, the ancestral Jhelum river can be shown to have been constrained in an area adjacent to its modern course approximately 2.5 million years ago. The ancestral river deposited multi-storied sands up to 200 meters thick in its axial channel areas, while adjacent areas are shown to have received sands averaging 10-15 meters in thickness at the same point in time.

Figure 3 demonstrates this relationship by examining a cross section from Ganda Paik to Kas Guma running approximately perpendicular to the flow direction of the ancestral Jhelum river. The schematic section shows the relative thickening of the sand bodies towards the axial region. In this manner the locus of the ancestral river can be determined. The ancient path of the Jhelum River, like its modern course, was structurally controlled by the Jhelum re-entrant (Visser and Johnson, 1978). The Jhelum re-entrant presents a convergence of fold trends which encourage the river to escape at the axis of convergence where few fold axes need be breached in order for the river to run out onto the plains (figure 1).

Figure 4 illustrates the progradation of conglomeratic facies from the north to the south. At Rata-Dudial, north of Mangla Reservoir, the conglomeratic facies is first evident in rocks that are 2.4 m.y. old. To the south, at Kas Guma, the conglomerates do not enter the section until about 2.2 m.y., and they are thin and sparse. Further south, at Rhotas the conglomerates do not occur until well after 1.9 m.y. Thus we can depict and quantify the southwards migrating facies change associated with the prograding alluvial fan sequence of the Himalayan foothills.

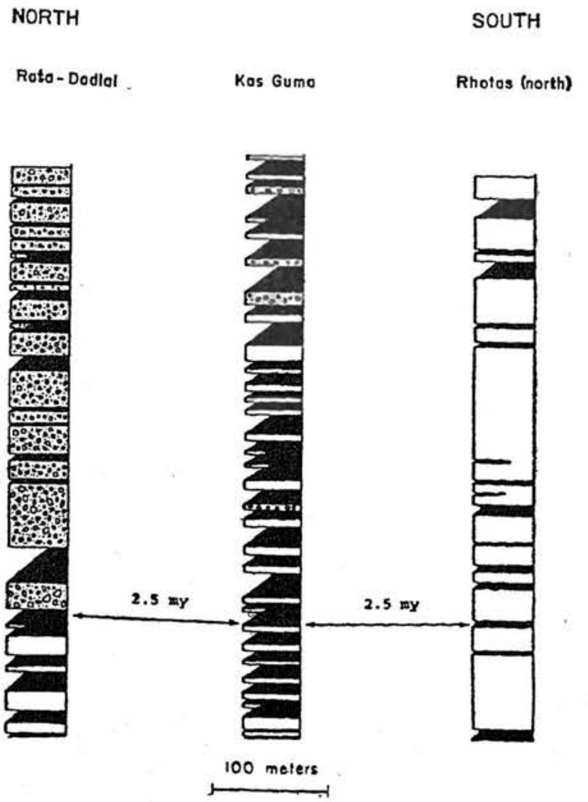

Fig. 4 Examples of lateral facies change due to prograding alluvial fans. The northern sections carry coarse conglomerates at a time when those to the south are receiving only sand and shale. Rata-Dadial is separated from Kas Guma by 37 km which in turn is separated from Rhotas (north) by 27 km.

CONCLUSIONS

The application of paleomagnetic stratigraphy allows the Siwalik molasse basin to be precisely dated. The old formation designations shall be re-evaluated in this light and the entire region re-mapped with time lines. Facies and heavy mineral suites will be seen as time transgressive and related to individual rivers and local deformational histories in addition to basin-wide changes in paleoclimate and paleogeography.

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