to store and accumulate salt. Electromagnetic techniques were generally used to produce maps that provide qualitative indication of near surface distribution of salt affected soils. These areas were then targeted with deeper-penetrating ground electromagnetic instruments to determine the depth continuity and likely size of deeper salt-storages and storage mechanism. AEM data are most directly suited to the diagnosis, prognosis and treatment of salinity. Magnetic (derivative, reduced to pole) images were used to map geological structures that are not always apparent from outcrop or airphoto interpretation.

Papers in this volume have shown conclusively that there is a wealth of information and knowledge that can be gained from the use of airborne geophysics to define the hydro-geological environments, clay mineral content of soils, groundwater quality and basement geology within any proposed irrigation area.

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REPORT ON THE INTERNATIONAL FIELD WORKSHOP ON THE VINDHYAN BASIN, CENTRAL INDIA

Mankind has been attracted towards the Vindhyan ranges in central India since Palaeolithic times when they chose it for their dwellings and cave paintings. The riverbeds draining the Vindhyans were combed for diamonds during the last few centuries. But the recent spurt in scientific discoveries in various spheres of Vindhyan geology have drawn the attention of the global scientific community and resulted in wide ranging discussions (fossil discoveries: Seilacher et al. 1998; Azmi, 1998; Kumar, 1999; Kathal et al. 2000, stable isotopes data: Friedmann et al. 1996; Friedmann and Chakraborty 1997; Kumar, 1991, 1999, radiometric dates: Kumar et al. 2001, Ray et al. 2002 and Rasmussen et al. 2002).

To assess, debate and discuss these geological findings, The Palaeontological Society of India and Geology Department of the Lucknow University' organized an International Field Workshop on Vindhyan Basin from 3rd to 11th December 2002. To understand the problems of Vindhyan Basin and its importance in terms of biological evolution, 34 participants from various parts of India and other countries drawn from universities, institutions and academia vitally interested in recent developments in Vindhyan geology assembled at Varanasi.

On 4th December 2002, team members visited the Kaimur and Semri groups of rocks exposed in Varanasi and Son-Bhadra districts. The excellent outcrops of the Kaimur Group near Adalhat about 24 kms from Varanasi and close to south of Arhaura (36 kms from Varanasi) were examined. Participants discussed the coastal/fresh water deposition of the sediments of Dhandraul Quartzite. Recent studies indicate that depositional models proposed earlier need revisions because of the new information and facies analysis studies carried out in the Vindhyan Basin. They were shown the excellent exposures of Rohtas Limestone Formation in the abandoned Ghurma Mine where the contact between the Semri and the Kaimur groups is well exemplified. Porcellanite samples were collected on the Dala-Chopan Motor Road Section where good exposures are present. A faulted contact between the Basal Conglomerate of Vindhyan Basin and Bijawar Phyllites of Mahakoshal Supergroup half a km from Dala Township towards Billi was shown to the participants to help understand the Vindhyan succession in the correct perspective. Another outcrop of the same phyllites about 3 km from Dala township was also visited. These phyllites are intensely folded and well exposed on either sides of the motor road.

On 5th December, team members saw the best-exposed lower and middle parts of the Kajrahat Limestone in the Dala Mines where a gradational contact between Basal Conglomerate and Kajrahat Limestone exists. Participants got an opportunity to visit Salkhan Hillock where excellently preserved *Conophyton* stromatolites are found in the Fawn Limestone Formation. Cherts associated with stromatolites have yielded a rich Precambrian microflora. Wide-ranging discussions among the experts, media, local administration and people of surrounding villages were held on the outcrop on the study and origin of stromatolites and preservation of the site. The only section of Olive Shales Formation underlying the Fawn Limestone Formation was examined on either side of the Lift Canal Pumping Station in Son-Bhadra District. In another section, various types of stromatolites were noted in the dolomite beds of the hillock in another abandoned mine of Bari. The columnar stromatolites of both Salkhan and Bari show NE inclination

indicating the probability of earth's inclination towards the Sun at the time of their formation.

Another younger group of Vindhyan sediments called Rewa were examined in the Drummandganj Ghat Section on 6th December where the Panna Shale Formation is exposed at the base of the hillock followed by Lower Rewa Sandstone, Jhiri Shales and Upper Rewa Sandstone formations. Carbonaceous fossils although known from the Jhiri Shales were yet not found in the field.

As per the itinerary the entire team moved for Rewa-Chorhat Section on 7th December to see the traces of triploblastic remains reported by Seilacher and others (1998). These rocks are exposed to east of Govindgarh some 20 km from the Rewa where the Upper Rewa Sandstone is underlain by the Jhiri Shales and the Lower Rewa Sandstone. Differentiation between Kaimur Sandstone and Lower Rewa Sandstone is still a lithostratigraphic problem in this area. At Chorhat, profuse development of ripple marks both current and wave ripples, mud cracks, synaresis cracks, sole marks, flute casts, drag marks etc. present on either side of the road gives one the feeling of glancing through text book example of sedimentary structures. In spite of the variety of sedimentary features the participants got a bit disillusioned not to find any traces of triploblastic remains or even any distant biogenic structure in the area. The controversy debated for long on the abiogenic features recorded as biogenic traces was thus set to rest. Another exposure of porcellanite similar to what was seen in Dala-Chopan motor road section was collected in the Son Valley Section south of the Chorhat Township for fossils studies.

On 8th December, participants were shown the Tamas River Section having good outcrops of the Bhander Limestone. In the afternoon the team members visited the typical Vindhyan scarp in which the youngest horizon of the Vindhyan Supergroup – the Maihar Sandstone Formation is exposed on the Maihar-Rampura Section. Extensively good sedimentary features and algal mat textures were visible here. Such textures are considered to be death traps for early animals. Underlying Sirbu Shales in the same section in which previously Kumar and Srivastava (2001) noted *Chuaria* and *Tawuia* were collected by the participants for examining the carbonaceous remains in the laboratory.

On 9th December, majority of the team members collected samples of Bahgwar Shales exposed in Badanpur-Sarlanagar Section for maceration to check and duplicate the Azmi's claim. Kajrahat Limestone of the Semri Group is well exposed on the beds of Chhoti Mahanadi River. The Middle Member of this Limestone is biohermal with several cycles of varied types of stromatolites including *Conophyton, Colonnella, Calypso, Thyassagetes* and *Jacutophyton*. Incidently here too the columnar stromatolites show NE inclination indicating heliotropism in organosedimentary structures. All the participants expressed their concern and urgency for the study of stromatolites of this locality as these are going to be submerged soon after the construction of Ban-Sagar Dam on the Chhoti Mahanadi River by the year 2005.

Post dinner informal presentations and discussions at camping sites were rewarding with many bits of interesting new information. The geophysical data presented by the General Manager Mr. Jokhan Ram of ONGC Ltd. showed that there is clear angular unconformity between Semri and Kaimur at certain places whereas at other spots the same succession seems to be concordant. Reports of the gravity low over Bundelkhand Granite Complex (BGC) near Jhansi has been interpreted in terms of thrusting of BGC over Semri sediments. Prof. Bruce Runnegar told the participants about the interesting fossil remain *Grypania* and its antiquity in the world record. Prof. Hans Hofmann presented data on pseudofossils, dubiofossils and true fossils on a novel biogenecity scale of numerical value 5 and cautioned palaeobiological workers against hasty publication of metaphyte and metazoan remains. He showed slides of various sedimentary features including some on volcanic rocks that could easily be mistaken for fossils. Dr. Bijai Prasad of ONGC in his presentation showed the presence of interesting acritarchs including *Tapania plana* in the subsurface Vindhyan equivalent sediments and in the sediments of recently drilled bore holes. His findings suggested that Semri Group is Mesoproterozoic in age while the younger formations belonging to Kaimur, Rewa and Bhander are Neoproterozoic in age and therefore Vindhyan basin sediments do not transgress into Cambrian and their sedimentation terminated well below the terminal Proterozoic. In another presentation, Azmi reiterated his claim of occurrence of small shelly fauna (SSF) in the Semri Group sediments based on a new set of samples. Objects shown in slides and samples though akin to SSF could not convince all the participants.

This weeklong sojourn of the field workshop concluded with the valedictory session at the world famous Khajuraho temple-town. Y.B. Sinha, Director (Explorations) ONGC chaired the session and Prof. S. Kumar, Organizing Secretary of the workshop moderated the session. Participants expressed their views about the field workshop and proposed recommendations. The secretary of 'The Palaeontological Society of India', Prof. M. P. Singh thanked all the participants and sponsors for the successful organization of the field workshop. Team members unanimously appreciated the nicely arranged field workshop showing many facets of

Vindhyan geology and multicultural life of India It was felt that such on the spot discussions among the experts would solve some of the vexed problems of Vindhyan geology

Recommendations

Following recommendations emerged on the basis of discussions among the participants and the views expressed during the valedictory session

(1) In view of the contradictory age connotations for the Vindhyan sediments, there is an urgent need to generate reliable radiometric dates by using latest available techniques The age of the Vindhyans has serious implications both for the hydrocarbon search as well as for evolutionary palaeobiology

(2) Available data on microfossils, megafossils and stromatolites need close scrutiny for their utility in biostratigraphy The following points need special attention (a) Potential of acritarchs and other microfossils should be studied for age implications and for intrabasinal and interbasinal biostratigraphic correlation Available records of metaphytes and metazoan should be evaluated for establishing their biogencity and for affinity with living forms (b) Stromatolites occurring extensively in Vindhyan Basin appear to be very useful for intra-basinal correlation but much needed taxonomically reliable data is not available for identification of groups and forms and also for comparison Efforts should be made to generate the relevant data Study of heliotropism in stromatolites during Vindhyan sedimentation should also be taken up Astropalaeobiology is a new dimension of Precambrian Palaeobiology to be pursued in coming days (c) The Vindhyan sediments have an excellent potential for preservation of megafossils, which will help in better understanding of evolution of life during Proterozoic having local as well as global implications Occurrence of the carbonaceous megafossils appears to be facies controlled Therefore extensive search be made for new fossil horizons (d) Recorded evidence of animal activity in the Vindhyan sediments should be properly evaluated and attempts should also be made to search them especially in the upper Vindhyans

(3) Concerted efforts should be made for establishing sequence and chemostratigraphy to solve the problems of lithostratigraphic correlation

(4) There are conflicting reports about the depositional environment for the different formations of the Vindhyan Supergroup Extensive sedimentological studies across the basin are required to understand the sedimentation patterns and nature of the Vindhyan Basin There is also an urgent need to find India's place in the tectonic set-up of Rodinia

(5) The local geological information available with Geological Survey of India, State Directorates of Geology and Mining and Oil and Natural Gas Corporation Limited etc should be published to help future research workers Drill core material should be made available to interested workers

(6) It is recommended that in future, GPS values (for longitude and latitude) should be mandatory for palaeontoligical publications for the precise location of the reported samples both for authors and editors publishing the results

(7) International collaboration should be encouraged specially in the field of palaeomagnetic study, dating of rocks and astropalaeobiology DST should be requested to take a lead in this direction

(8) A few sections of the Vindhyan succession have good potential to become tourist attraction Basic amenities should be provided on such sections These must be preserved for educating school children and public about the early life on earth and its significance

An outreach programme can do marvels as exemplified by the Salkhan villagers, district authorities and media coverage Such efforts are to be made for other geologically important spots requiring conservation Though the Uttar Pradesh (U P) Government has made a beginning in this direction by declaring Salkhan Hill site in Son-Bhadhra district, U P as a 'Fossil Park', which is now a protected site It is hightime that the Government should enact a law on 'National Geological Heritage' for conservation, study, trading and export of such material

(9) A serious effort should be made to conserve the Chhoti Mahanadi Section of stromatolites by way of recording the stromatolites, shifting some typical forms to the Institutions/Museums/Universities before it is submerged due to dam building

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STRUCTURE AND TECTONICS OF KUTCH BASIN, WESTERN INDIA, WITH SPECIAL REFERENCE TO EARTHQUAKES*

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EXTENDED ABSTRACT

The Kutch basin is a western margin pericratonic rift basin of India The rift is bound by Nagar Parkar uplift in the north and Kathiawar uplift (Saurashtra horst) in the south respectively along Nagar Parkar and North Kathiawar faults The rift is styled by three main uplifts along three master faults with intervening half-grabens (*see* Fig 2 in Biswas and Khattri, 2002) The uplifts are upthrust basement blocks tilted along sub-vertical faults with normal separation The North Kathiawar fault is the principal master that along which the rift subsided most The structure is thus styled by tilted footwall blocks and half-grabens Blanketing sediments over the basement drape over the tilted edges of the upthrusts as marginal flexures The flexures are narrow deformation zones along master faults enclosing complicated folds, locally much faulted and intruded by igneous rocks

A subsurface basement ridge – Median High, crosses the basin at right angles to its axis in the middle It divides the basin into a deeper western part and a shallower and more tectonised eastern part The rift is terminated in the east against a transverse subsurface basement ridge Radhanpur Arch, which is the western shoulder of the adjacent N-S oriented Cambay rift To the west the rift merges with offshore shelf, which is styled by NW-SE trending shelfal horst graben systems

The Kutch basin is the earliest pericratonic rift basin to form in the western margin of the Indian craton during the Late Triassic breakup of Gondwanaland (Biswas, 1982) The rift evolution and syn-rift sedimentation continued through Jurassic till Early Cretaceous as Indian plate drifted northward along an anticlockwise path During post-rift stage, the Tertiary sediments were deposited on the peripheral plains of the uplifts The rift expanded from north

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