Volume 12 August 1995 Special Issue

JOURNAL

OF

NEPAL GEOLOGICAL SOCIETY

ABSTRACT VOLUME

FIRST NEPAL GEOLOGICAL CONGRESS

15-16 August, 1995

KATHMANDU, NEPAL

Journal of Nepal Geological Society
EDITORIAL BOARD

First Nepal Geological Congress
15 - 16 August, 1995

Organised by

NEPAL GEOLOGICAL SOCIETY

Sponsored by:

Department of Mines and Geology
Department of Irrigation
Central Department of Geology, Tribhuvan University
Petroleum Exploration Promotion Project, HMG
Groundwater Resources Development Project, HMG

Supported by:

Godavary Marble Industries (P) Ltd.
SILT Consultants (P) Ltd.
National Drilling Company (P) Ltd. (NADCO)
ITECO Nepal (P) Ltd.
TAEC Consult (P) Ltd.
Multi Disciplinary Consultants (P) Ltd.
METCON Consaltants (P) Ltd.
GEOCE Consultants (P) Ltd.
EAST Consult (P) Ltd.
EAST Soil Lab & Drilling Company
National Drilling Company of Nepal Ltd.
Nepal Environmental & Scientific Services (P) Ltd.
Sub-Structural Consult (P) Ltd.
CEMAT Consultants (P) Ltd.
Himalayan Sherpa Coal Udhyog

FIRST NEPAL GEOLOGICAL CONGRESS

Organising Committee

Convenor

Mr. Krishna Prasad Kaphle President, Nepal Geological Society	*Department of Mines and Geology*

Co-Convenor

Dr. Dibya Ratna Kansakar Vice President, Nepal Geological Society	*Groundwater Resources Development Project, DOI*

Members:

Dr. C. K. Sharma	*Royal Nepal Academy of Science and Technology*
Dr. B. N. Upreti	*Department of Geology, Tri-Chandra Campus*
Mr. Y. L. Vaidya	*Department of Irrigation*
Mr. N. B. Kayastha	*Department of Mines and Geology*
Dr. R. P. Bashyal	*Petroleum Exploration Promotion Project*
Dr. M. P. Sharma	*Tribhuvan University*
Dr. P. C. Adhikary	*Central Dept. of Geology, T. U.*
Dr. R. B. Shrestha	*Petroleum Exploration Promotion Project*
Mr. A. M. Dixit	*SILT Consults (P). Ltd.*
Mr. A. N. Bhandary	*Maiti Devi, Kathmandu*
Dr. R. M. Tuladhar	*Groundwater Resources Development Project, Birgunj.*
Dr. M. R. Dhital	*Central Dept. of Geology, T. U.*
Dr. A. B. Singh	*Institute of Engineering, T.U.*
Mr. N. D. Maske	*Lazimpat, Kathmandu.*
Mr. R. K. Aryal	*Department of Mines and Geology*
Mr. S. P. Pradhan	*Electricity Development Centre*
Mr. T. P. Adhikary	*Department of Mines and Geology*
Dr. T. Sharma	*Nepal Environmental and Scientific Services (P) Ltd.*
Dr. P. Gautam	*Central Dept. of Geology, T. U.*
Mr. B. D. Shrestha	*Department of Soil Conservation*
Mr. U. M. S. Pradhan	*Department of Mines and Geology*
Mr. K. Karki	*Department of Mines and Geology*
Mr. B. R. Aryal	*Department of Mines and Geology*
Mr. S. B. KC.	*Department of Mines and Geology*
Mr. D. N. Subedi	*Department of Mines and Geology*
Mr. S. R. Sharma	*Department of Mines and Geology*
Mr. U. B. Pradhananga	*Department of Mines and Geology*
Ms. R. Shrestha	*Groundwater Resources Development Project, DOI.*
Mr. S. R. Bajracharya	*Department of Geology, Tri-Chandra Campus*
Mr. S. Giri	*Soil Test Lab.*
Mr. D. Sadaula	*Electricity Development Centre*

PREFACE

The Nepal Geological Society is completing fifteenth year of its birth. In these past fifteen years, the Society has taken several steps forward in advancing the study and research in the field of earth science in the Himalayan region. The Society has grown continuously in its membership size and has been able to foster a closer network among the earth scientists of the world working in the Himalayan region.

In advancing further the objectives of the Society in its professional development and scientific activities, the Society is organsing the FIRST NEPAL GEOLOGICAL CONGRESS to mark its fifteenth anniversary. It is a bold step forward in the direction of professional development and closer cooperation among the earth scientists of the world. The Society intends to organise such congress regularly in future also.

The Society is greatly encouraged by the response of geo-scientists to the call of participation in the First Nepal Geological Congress, not only from its members but also from the prominent earth scientists from many countries of the world.

The Society would also like to extend its sincere appreciation to all the participants and contributors as well as all the well wishers for making this Congress a remarkable event.

Lastly, financial assistance received from ITECO Nepal (P) Ltd., TAEC Consult (P) Ltd., METCON Consultants (P) Ltd. and Multi Disciplinary Consultants (P) Ltd. to bring out this abstract volume is thankfully acknowledged.

Contents

Hydrogeology

Geo-Environment

Geo-Science and Infrastructure

Mineral Resources

The Cenozoic of Nepal: Mountain Elevation and Vertebrate Evolution

ROBERT M. WEST
RMW Science Action, Washington, DC, USA

The Cenozoic of Nepal was a time of great activity, in terms of both the establishment and uplift of the Himalaya and the development of a vertebrate fauna which changed through time in response to the environmental events caused by the elevation of the mountains. Field work conducted over the past twenty years has generated a body of data which brings together paleontological, ecological and tectonic interpretations of the Cenozoic history of the Nepal Himalaya.

Paleontological data from Nepal is geographically limited. At this time, the early Cenozoic is represented by modest marine mammal remains found near Pokhara, the middle and late Cenozoic is documented from abundant materials found in the Siwaliks in a broad band of sub-Himalayan sedimentary rocks between Butwal and Nepalganj, and Ice Age Nepal may be interpreted from several Pleistocene localities in the Kathmandu Valley.

Nepal's Cenozoic paleo-environments are interpreted in large measure from the fossils found in the areas mentioned above, as well as by analogy to India and Pakistan.

From selected fossils and localities it is possible to document the arrival of the Indian tectonic plate in South Asia in the early Cenozoic; at this time a broad open seaway (the remnant to Tethys) which occupied much of Nepal until the early Cenozoic closed and terrestrial communication with other areas became possible.

By the middle Cenozoic, Nepal was the site of major erosional deposition from the rising Himalaya. This paleo-environment is indicated by both the terrestrial clastic sedimentary rocks which dominate the Nepal middle and late Cenozoic sequence as well as by the particular vertebrate taxa which have been recovered from the Siwaliks in western Nepal.

Nepal's Pleistocene was a time of cool and dry environments; Kathmandu Valley deposits have yielded vertebrate remains which are indicative of this environment.

Of particular interest are efforts to relate Himalayan Cenozoic tectonics to the paleobiological record of Nepalese environments. There are strong indications that the primary elevation of the Himalaya was mid-to-late Cenozoic event; this correlates well with the environmental evidence from the fossil assemblages.

A major part of this presentation is devoted to coordination of tectonic, paleontologic, and sedimentary data which are used to interpret the Cenozoic history of the Nepal Himalaya.

Minerovilles: A Concept for Developing Mineral Deposits in the Developing Countries.

F. A. SHAMS
Centre for Integrated Mountain Research
Punjab University, Lahore, Pakistan

Minerals constitute the most important natural raw material that has the potential to revolutionize economy of developing countries of the world.

The use of minerals by man is equally old. From the early use of minerals as natural pigments to harnessing of nuclear energy, there is a continuous man-to-minerals relationship. Without the use of minerals, the mankind could have stuck at the Stone Age.

The Strategic importance of minerals was well displayed during the two world wars. The recent oil embargo and the conditions now prevailing in the mineral-rich countries show the geo-political impact of these resources.

The industrial bias of modern economies have led the mineral resources acquire unprecedented importance and increase in their demand. However, a recent survey have indicated that the presently known mineral deposits of the world may not last for more than 50 years. The advent of modern technologies have made it possible to recover metals even from old metallurgical slags that were left after exploiting high grade ores in the past. sadly, the developing countries still continue to be mostly raw material producers and major consumers of mineral based industrial products.

International trends show that some of the so-called low grade mineral deposits of the developing countries can now fetch better prices. On the other hand, some of the mineral commodities may have to be sold at lower prices in the competitive international market due to availability for development of larger and easily exploitable resources. It is important, therefore, that the best course of action for the developing countries is to utilize their mineral deposits more wisely and develop their own industrial base, rather than to concentrate only on export of raw material.

The present paper is meant to draw attention to rather neglected aspects of the problem that can be tackled easily through the existing financial and technical strength of the developing countries.

An Overview of Mineral Resources of Pakistan

M. ALI MIRZA
Geological survey of Pakistan, Quetta, Pakistan.

In 1947, when Pakistan came into existence only 5 mineral commodities were being mined on small scale and potential of finding minerals in the area which constituted Pakistan was not known. The Geological Survey of Pakistan through its enderverse has proven that Pakistan is geologically a unique country. Its land mass consists of rocks whihc were formed at oceanic centers, continental and oceanic Island area, deep oceanic to shallow marine and even continental sediments. These rocks, as elsewhere in the world, have been proved by the GSP to contain a large variety of mineral deposits.

It has now been proved that very large deposits of industrial minerals such as Gypsum and anhydride, limestone and dolomite, building stones, rocks salt, silica sand, barite, fullers earth, industrial clays and soap stone while medium size resources of magnesite China clays, and bentonite occur in the country.

Chromite is the only metallic mineral which is being produced on small scale since before independence but large scale production of copper from Saindak Porphyry Copper deposits will be starting very soon and large scale mining of Zinc lead deposit of Duddar is not very far, Favorabic areas of mineralization of aluminum, Chromium, Copper, Lead Zinc,. Gold, Silver, Iron, Platinum and Tungstan have been identified and it is expected that soon Pakistan will emerge as an important country on the metal producing countries of the World.

Only a couple of years back Pakistan had no position on the global map showing countries having large coal reserves but with the discovery of Thar Coal Field, with over 175 billion tones of good quality longnite, Pakistan has achieved 11th position among the countries having large coal reserves.

The prospect of making Pakistan an important mineral producing country are quite bright. Geological Survey of Pakistan is doing its best to explore the mineral potential of the country and disseminate data, so as to make people interested in exploration and exploitation of the mineral wealth of the country.

The Tectono-Stratigraphic Set-up of Higher Central Himalaya

ANSHU K. SINHA
Wadia Institute of Himalayan Geology, Dehra Dun, India

The Central Himalayan segment from S to N is divided into sub-parallel structural facies zones. The Main Boundary Fault (MBF) plays the role of an important tectonic element dividing the Siwalik Molasse along the foothills of the Himalaya against the para-autochthonous and allochthonous tectonic units of the southern Himalaya. On the basis of recent researches I suggest that the Himalayan region should be divided geologically into two major geologic zones. I propose that the dividing structural line between them be termed the Main Axial Zone (MAZ) of the Himalaya, which is situated in the crystalline complex of the Higher Himalaya. This deep-seated structure in the Himalaya has played a crucial role in the history of geological development and also incorporates the root zone of the southward-pushed thrust sheets. The Main Central Thrust (MCT) tectonically separates the carbonate para-autochthonous zone of the southern Himalaya from the metamorphosed crystalline 'Vaikrita Complex'. The Vaikrita Central Crystalline Complex in turn is separated from the huge pile of the sedimentary Tethyan Complex by the 'Tethyan Thrust' (TT). Farther north the 'Great Himalayan Suture' (GHS), termed the Indus-Tsangpo Suture, divides the northern extremity of Himalaya from the Karakoram orogenic belt. The GHS has provided excellent conditions for the study of mantle remains on the oceanic crust with the occurrence of an ophiolitic melange, which was the result of subduction of a continental type plate and abduction of oceanic material.

Tectono-stratigraphically the Tethyan zone of Higher Central Himalaya represents a most fascinating stratigraphic column from Precambrian to Eocene. The area, since the study of Griesbach (1881) till Heim and Gansser's work (1939), and subsequently during the later period of post-independence of India-has been the classical area to study the basic geological features of Himalayan mountain belt. During two decades of research period author (Sinha, 1981, 1987, 1989, 1992 and in Press) could make an extensive study and mapping of the area in large scale and discovered the new fossils and tectonic features. The tectono-stratigraphic evidences further confirmed to the new models based on the concept of the plate tectonics.

It has been contended that Himalayan mountain building is the product of a collision between the Indian and Eurasian plates which began during the Eocene epoch. This collision between the Indian and Eurasian continents is considered to be one of the major tectonic events in the Cenozoic era. An initial collision age of about 50 million years has been estimated with an average convergence rate of about 50 mm per year, although a direct measurement of the amount of shortening is often not possible and each method has remained controversial in the case of Himalayan orogen and associated Tibetan plate. On the basis of paleomagnetic data, after considering the motion of the Indian plate, it has been calculated that the total amount of North-South crustal shortening which followed the collision is in the order of 2600 ± 900 km. Crustal shortening in major orogenic belts involves, in addition to folding, one or several modes of deformation, subduction of continental crust in the wake of pre-existing oceanic subduction, and sideways escape of crustal blocks along major strike slip faults.

References:

Griesbach, C.L., 1981. Geology of the Central Himalayas. *Rec. G.S. I., 23, 232pp.*

Heim, A. and Gansser, A., 1939. Central Himalaya, Geological Observations of the Swiss Expedition 1936. *Mem.Soc.Helv.Sci.Nat., 73(1), 1-245.*

Sinha, A. K., 1981. Geology and Tectonics of the Himalayan Region of Ladakh, Himachal, garhwal-Kumaun and Arunachal Pradesh: A Review. *In: Zagros, Hindkush Himalaya Geodynamic evolution. H. K. Gupta and F. M. delany (eds.). American Geophysical Union, Washington, 3, 122-148.*

Sinha, A. K., 1987. Tectonic Zonation of the Central Himalaya and the Crustal Evolution of Collision and Compression Belts. *Tectonophysics, 134, 59-74.*

Sinha, A. K., 1989. Geology of the Higher Central Himalaya. *John Wiley and Sons, Chichester, U.K., 236pp.*

Sinha, A. K., 1992. Himalayan Orogen and Global Tectonics. *Oxford & IBH/A.A. Balkema, Netherlands, 343pp.*

Sinha, A. K., (In press). Geodynamic Domains in Alpine Himalayan Tethys. *IGCP 276 Special Publ. of GC, Japan,1992.*

Groundwater Development : Its Environmental Impact

M. Hoque

Bangladesh University Grants Commission, Dhaka, Bangladesh

Bangladesh is a country of rivers and flooding is an annual phenomena. Despite her having enormous volume of surface water during the monsoon, the country is heavily dependent on groundwater for irrigation and domestic water supplies. About 70% of the irrigation water requirement and more than 90% of potable water supply comes from groundwater resources. Groundwater abstraction has increased extensively over the last two decades and thousands of irrigation and water supply bore holes have been developed at different parts of the country.

Groundwater development in most cases are interrelated with positive and negative socio-economic aspects and environmental issues. Bangladesh is not an exception. Positive impacts are providing irrigation coverage for larger areas, supplying good quality water for greater percentage of the population and remarkable improvement in controlling the water borne epidemics like Cholera and Typhoid. On the other hand, large scale ground-water abstractions in many parts of the country is found to be associated with adverse effects like lowering of the water table, water pollution, intrusion of saline water into groundwater in the coastal areas and far inside the country, occurrences of biogenic gas in irrigation wells and change in surface/ground water interaction. Possibilities of land subsidence in urban areas have also been talked about.

A generalized picture of environmental impacts of large scale ground water development will be presented. Number of case studies concerning both positive and negative environmental impacts will be discussed. Impact of large scale irrigation and flood control schemes, urbanization, industrialization, agricultural practice and present land use pattern on regional hydrogeology of the country will be highlighted.

Landslide Studies in the Himalayas

V. D. CHOUBEY

Engineering Geology Division, Indian School of Mines, Dhanbad, India

In recent years there have been several major landslides in Himalayas and following these disasters, a comprehensive research programme of slope stability investigation was initiated. The programme has involved (i) detailed inspection and documentation of landslides and related deformations, (ii) monitoring of slides and related deformation to structures, (iii) a few cored small diameter diamond drill holes with piezometers installed for obtaining pore water pressures, (iv) laboratory studies mainly the shear strength characteristics of slide materials and (v) critical examination of documented case studies by other organisations. Key factors for the landslide hazard are discussed with the principal aim of identifying potential risk areas. The results make it possible to assess the stability and to understand the mechanism of slide developments and for making recommendations of remedial measures based on analytical calculations of stress deformation conditions and of rock slope stability computations.

Regarding the mechanism of the landslides, it is concluded that the slope stability problems are caused mainly for three reasons : (i) a tropical climate is conducive to deep weathering causing strength losses and permeability changes that lead to a reduction in stability of natural slopes; (ii) the intense rainfall results in rapid erosion, raising the groundwater level and saturating the overburden materials; (iii) the seismo-tectonic activity and the presence of several major faults and lineaments in Himalayas are responsible for placing these areas at high risk level for slope failures.

Among the recommendations made, the principal one is that a major programme of shear strength testing and back analysis of failed slopes be implemented in order to provide reliable values of shear strength characteristics for designing the remedial measures. A brief review is also included for the Terrain Classification and Landslide Hazard Zonation approach. This paper summarizes the engineering geological and geotechnical investigations, assesses the slope stability and make recommendations on a combination of remedial measures, specially the drainage control for improving the slope stability in complex seismo-tectonic environment. These investigations assume a special significance in context with the currently on-going United Nations Decade of Natural Disaster Reduction Programme.

Structure and Tectonics of Eastern Folded Belt of Bengal Basin

MONIRUL HOQUE
University Grants Commission, Dhaka, Bangladesh
and
A. M. SIKDER
Bangladesh Petroleum Institute, Dhaka, Bangladesh

The Eastern Folded Belt of Bengal Basin is the folded part of the western foreland basin of the Indo-Burman Range. Present study reveal that history of the tectonic development of the Eastern Folded Belt is much more complex than the presumption from surface geological information. It is evident from the seismic interpretation that multi-component stress situation of several phases were responsible for the development of the Eastern Folded Belt of Bangladesh.

The complex nature of Eastern Folded Belt of Bengal Basin could happen only in the case of thin skin tectonics triggered by tectonic compression over a regional detachment because the timing of structural development of the Eastern Folded Belt of Bengal Basin as interpreted from reflection seismic does not match with the history of the subduction tectonics of the region.

The reflection seismic interpretation also reveals rotation of the anticlinal structures over the detachment plane, which is likely an indication of compressional rotation due to the presence of thick under-compacted shale at the core of the anticlinal structures. The thick under-compacted argillaceous sequences probably accelerated the tectonic compression to develop the complex folds over regional detachment plane.

Lithostratigraphy of Siwaliks of Katari Area, Eastern Sub-Himalaya, Nepal

R. B. SAH, B. YADAV and N. K. THAKURI
Central Dept. of Geology, T.U., Kathmandu, Nepal

Katari lies in the eastern part of the Nepalese Sub-Himalaya. It is in the vicinity of Kamala River. This area is very unique for the Siwaliks of Nepal. A complete succession of Siwalik rocks is well developed. A well marked angular unconformity separates the Siwaliks from the underlying Precambrian-Cambrian rocks of Lesser Himalaya. The Lesser Himalayan rock succession is more than 200 m thick and consists of dolomites which are bluish grey in color, massive and contain columnar and dome shape stromatolites.

The Siwalik rock succession of Katari area has been classified into six mappable litho-stratigraphic units. From bottom to top they are: Katari Formation, Kakaru Formation, Ghurmi Formation, Belsoth Formation, Garas Formation and Tribeni Formation. The contact between each unit is transitional.

At the base of Katari Formation, near Bhoregaon, about 2 m thick basal conglomerate layer is well exposed. The conglomerate bed consists of pebble-cobble clasts of dolomite, slate and quartzite. The unit is composed of a rapid alternation of variegated mudstones chiefly of red, purple and yellow color. The sandstones are thinly bedded, mottled, fine grained and calcareous. The unit is 1750 m in thickness.

The Kakaru Formation is well developed in the north of Katari Bazar. It is about 900 m in thickness and is composed of variegated mudstone and sandstone. This sequence is more sandy, the sandstone beds being massive and thicker (5-10 m) than those in the previous unit. It often contains ripple marks, cross-beddings and medium grained sandstones. Layers of greenish grey mudstone and medium grained micaceous sandstone begins to appear.

The Ghurmi Formation represents a major change in the lithological succession of the Siwaliks in the Katari area. The unit is entirely composed of greenish grey mudstone and micaceous medium grained thick bedded

sandstone. The proportion of mudstone to sandstone is nearly equal. Some layers of marls have also been observed at the lower part of the sequence. A crocodile tooth and some leaf imprints have been discovered from the top part of the sequence. The unit measures 1250 m in thickness.

The Belsoth Formation is distinct in lithological composition. It is made up of loose, less indurated thick beds (50-60 m) of medium to coarse grained micaceous sandstone and grey to black mudstone. The sandstones look like a mixture of "pepper and salt" and often contain coalified tree trunks. The sequence contains several horizons of highly calcareous ferrugenous concretions, tubes and sandballs towards the top. Large scale cross-beddings, fill and cut structures and sole markings are frequent. The unit is about 750 m in thickness.

The Garas Formation is well developed in the vicinity of the village Garas. It consists of alternations of well sorted pebbly-gravely conglomerate, medium to coarse grained micaceous sandstone and grey to black mudstone. The sediments are loose to semi-consolidated. The clasts of conglomerates are composed of quartzites, marbles, slates and granites. A very hard, highly consolidated pebbly conglomerate bed forming ridge marks the top of this sequence. This unit is about 600 m in thickness.

The Tribeni Formation is composed entirely of ill-sorted, loose pebble-cobble conglomerate with some lenses of sandstone and mudstone. The conglomerate is mainly composed of rounded to sub-rounded clasts of quartzites, sandstones, limestones, granites and marbles. The unit measures about 700 m in thickness and is covered by terrace deposits.

A Review of the Geology of Northwest Himalaya

M. N. CHAUDHRY and M. GHAZANFAR
Institute of Geology, Punjab University, Lahore, Pakistan

Mapping and studies of extensive areas of Northwest Himalaya in Pakistan has now enabled us to present a tectono-stratigraphic division and characterization of this complex terrain.

Prior to our studies and synthesis neither the extent of Himalayan Domain nor the crustal scale shear zones like Main Central Thrust (MCT) and Trans Himadri Fault (THF) (extensional shear zone) were recognized nor indeed were the Tethyan Himalaya and the Higher Himalaya demarcated. Even the exact position of Panjal Thrust (PT) was not known. Everything north of the Panjal Fault in Kaghan and Neelum Valleys was grouped in an all inclusive Salkhala Formation which extended for more than one hundred kilometers in width.

The problems of metamorphic Proterozoic stratigraphy were not properly resolved and cross correlations between units of Lesser and Higher Himalaya and even within Lesser Himalaya were common.

In this paper we present the tectonic subdivision of the entire NW Himalayas in Pakistan based on our demarcation of THF and MCT as well as proper placement of PT and MBT in certain sections of NW Himalaya. In addition we have used the already known positions of MMT, MKT and HFT to build a proper tectonic net of NW Himalayas in Pakistan. From south of north between HFT and MBT lies the outer Himalaya, between MBT and PT lies the Lesser Himalayan sedimentary block, between PT and MCT lies the Lesser Himalayan metamorphic zone, between MCT and THF lies the Higher Himalaya, between THF and MMT lies the Tethyan Himalaya and between MMT and MKT lies the Kohistan Himalaya. Between MKT and Yenshan suture zone lies the Karakoram Himalaya.

We consider the Karakoram plate as a continuation of the pre-Triassic Himalayan package with a Proterozoic basement similar to Higher Himalaya and the overlying sediments as a part of the former much more extensive Kashmir-Peshawar basin. This Karakoram microplate extended up to Yenshan suture in southern Tibet. This terrain is hereby named as Karakoram Himalayas.

1. Outer Himalaya

The outer Himalaya lying between MBT and HFT is composed of Molassic foredeep deposits of Murree Formation and Siwalik Group. The northern part of outer Himalaya is tightly folded and strongly compressed in Hazara and Kashmir. At places the zone has been strongly disrupted upthrusting structures like Balakot Muzaffarabad and Salt Range. The strongly deformed and less deformed zones are separated by Muzaffarabad-Jammu-Riasi uplift zones of Kashmir and Khairi Murat anticlinal zone of Potwar. Murree Formation generally considered Miocene may extend down to Oligocene in Changal area of Azad Kashmir and probably Upper Eocene in Kuldana-Murree areas. Elsewhere in Kohat-Potwar basin it is Miocene in age.

2. Lesser Himalaya

The Lesser Himalaya is characterized by a complex central tectonic block of Kaghan-southern Neelum and Northern Hazara characterized by a complex schuppen structure. This block is flanked to the east by Kashmir basin and to the west by the Peshawar basin. These basins exhibit simple open fold structures with fewer faults.

A four phase deformation has been identified in southeast Hazara with a first (D1) Pan-African phase followed by three (D2, D3 and D4) Himalayan phases. D2 is reflected in south verging folds and thrusts, D3 is characterized by north verging structures while D4 results in north-south open cross folds ending in the formation of HKS.

Three tectonically juxtaposed distinct stratigraphic provinces have been recognized on the boundary of Hazara and Kashmir. The Tanawals of Kashmir and Tanols of Hazara were formerly recognized as equivalents. However we regard these units as stratigraphically distinct and different in age. The Tanawals are Devonian to Carboniferous in age while Tanols are Precambrian in age. Tanols are regarded younger than Hazara Slates. However, we consider Tanols to be older than Hazara Slates.

The Permo-Carboniferous NW Pakistan Alkaline Igneous Province is continental rift related province complimentary to plume induced Panjal Volcanics of Kaghan and adjoining Kashmir which exhibit PMORB type oceanic characteristics. This volcano-plutonic igneous province along with sedimentary packages constitutes a Taphro-orogenic Hercynide belt.

2. Higher Himalaya

The Higher Himalaya is composed of a mainly Lower Proterozoic granitoid migmatite basement with high grade mainly psammite-pelite metasediments and metasedimentary enclaves and is overlain by a cover sequence of pelite-psammite and calc-pelite with marbles and amphibolites. The whole sequence is metamorphosed to upper amphibolite facies. The HHC is characterized by doubly plunging generally N-S trending open basins and domes with a prevalent ductile deformation, and very few faults. The HHC block has suffered multiple orogenesis and polymetamorphism ranging in age from Lower Proterozoic to Tertiary. The block is characterized by at least six phases of deformation. D1 is characterized by relict schistosity and crenulation now preserved as relicts in garnet porphyroblasts. D2 is marked by rootless intrafolial folds; D3 is characterized by NW-SE trending structures; D4 is characterized by NE-SW cross folding culminating in N-S trending doubly plunging open basins and domes. D5 is characterized by very open shallow E-W superposed folds which parallel the MMT. D6 is a fracture cleavage that cuts across the dominant schistosity as well as the porphyroblasts at a high angle.

The HHC block extends eastwards into Kashmir and westwards into adjoining NE Afghanistan. Northwards with a break it extends across the MKT into Karakoram-Lhasa plate.

4. Tethyan Himalaya

The Tethyan Himalaya is characterized by very low grade sediments composed mainly of carbonaceous/graphitic phyllites, slates, calc-pelites and marbles. They occur as thin slices which expand in Banna-Allai area and lie between MMT and THF. These sediments also occur as slivers within HHC. They may range in age from Eo-Cambrian to Palaeozoic.

5. Kohistan Himalaya

The Kohistan Himalaya is a composite oceanic island arc block. It is composed of two sutures namely MMT and MKT. The central part is composed of remnants of Tethyan crust and island arc volcano-plutonics. The northern parts represent a back arc trapped ocean.

6. Karakoram Himalaya

The Karakoram Himalaya lies between MKT and the Yenshan suture zone. It is composed of a Proterozoic basement of granitoids-migmatites with high grade metasediments and metasedimentary enclaves and an overlying high grade cover sequence of pelite, psammite, calc-pelites, marbles and amphibolites. In Hunza area it outcrops as what is known as Baltit Group. In Karakoram region it is overlain by a low grade to unmetamorphosed sedimentary package ranging in age from Eo-Cambrian to Permian. The overlying younger formations were deposited when this part of Himalayan domain had rifted away from India in post Permian period and became a part of Asia.

Geology of a Part of the Kohistan Terrane Between Gilgit and Chilas, North Pakistan : Regional Tectonic Implications

T. KHAN

Geoscience Laboratory, Geological Survey of Pakistan, Islamabad,

M. A. KHAN, M. Q. JAN

National Centre of Excellence in Geology, University of Peshawar

and

M. LATIF

Geological Survey of Pakistan, Northern Areas Directorate, Islamabad, Pakistan

Geological description on a previously unmapped area between Gilgit and Chilas, which is part of the Kohistan terrane is presented. This terrane is considered an intra-oceanic island arc, formed due to northward subduction of the Neo-Tethyan lithospheric plate. At present, it is squeezed between Karakoram-Asian and Indian continental plates; both the contacts between them being marked by suture zones i.e., MKT in the north and MMT in the south, respectively. The investigated area consists of plutonic and stratified metamorphosed volcanic and sedimentary rocks. Chilas Complex and Kamila amphibolites are also exposed. The stratified rocks are packed into the Jaglot Group. This group comprises ~> 1 km thick basal turbiditic sediments intercalated with amphibolites and calc-silicates (the Gilgit Formation), followed upward by >0.5 km thick Gashu-Confluence Volcanics = Chalt Volcanics and, finally the Thelichi Formation = Yasin Group Sediments of Albian-Aptian age. The Thelichi Formation comprises a volcanic base (Majne volcanics) and ~> 1 km thick overlying turbidites, local intercalations of marble, volcaniclastics and lava flows. Greenschist and amphibolite facies metamorphism is common in the Jaglot Group, and particularly the sillimanite in the Gilgit Formation. A pair of anticline (the Gilgit anticline) and syncline (the Jaglot syncline) make up the structural scenario. On the basis of field geology and laboratory studies, we conclude that the Gilgit and Thelichi formations exhibit turbidite affinities, sandwiching the island arc and back-arc basin-like Gashu -Confluence and Majne metavolcanics respectively. We further conclude that the entire Jaglot Group shows intra-oceanic back-arc basin signatures rather than island arc assemblages as suggested in the past.

North-South Continuity Across the Indus-Tsangpo Suture

F. AHMAD
Indian National Science Academy, New Delhi, India
and
Z. A. KHAN
Directorate Geology & Mining, Lucknow, India.

Gondwana glaciation is well known from the Indian sub-continent and pole must have lingered long enough in the Indian sub-continent to deposit glacio-marine sediments, some 1,600 m thick, entirely by ice-bergs, all over northern Tibet. These deposits bespeak unequivocally that India and Tibet (and hence the rest of Asia) were together in the Upper Carboniferous and Lower Permian. Other lines of evidence demonstrate this for the Permian, Triassic, Jurassic and Cretaceous. The collision is supposed to have taken place in the Eocene-Miocene, and there should at least have been a very short epoch of compression at this stage. Instead, the immense batholithic intrusion in the area suggests strong tension. Moreover, the ophiolites along the suture have yielded two different ages of emplacements, Jurassic-Lowest Cretaceous and then, Lower Cretaceous, i.e. the emplacement took place about 100 Ma before the supposed collision in the Eocene-Miocene. In the Quaternary, while the Indian plate is believed to be progressively subducting under the Tibetan plate, a large part of central and southern Tibet is cut by active normal and transform faults and rift valleys, cutting across the Bongong-Nuijiang and the Indus-Tsangpo suture zones and entering the Himalayan zone.

The collisional origin of the Indus-Tsangpo suture is, therefore a consequence of mis-interpretation and distorted arguments offered by supporters of plate tectonics hypothesis. India has all along been adjacent to Tibet, certainly at least since the Ordovician and hence a part of the great Pangaean landmass, till the later broke up, and of Eurasia since.

The Lesser Himalayan Crystalline Nappes: Are they Exotic Slices ?

B. N. UPRETI
Department of Geology, Tribhuvan University, Tri-Chandra Campus Kathmandu, Nepal

Ever since the recognition of the Crystalline Nappes in Kumaon by Heim and Gansser, a number of such nappes and crystalline thrust sheets have been mapped all over the Himalaya. The *Amri-Lansdowne Crystalline Klippe*, the *Almora Nappe*, the *Nandprayag-Baijnath Nappes*, the *Dharamgarh Nappe*, the *Askot Nappe*, the *Chiplakot or Munsiari Nappe*, the *Satengal-Banali Nappes*, the *Chamba Nappe* are the main crystalline nappes of Western Himalayas in India. Well known crystalline nappes in Nepal are the *Kathmandu Nappe*, the *Jajarkot Nappe*, the *Bajhang Nappe* and the *Dadeldhura Nappe*. A crystalline nappe also exists in the Karnali region of far western Nepal called the *Karnali Nappe* or the *Chakhure-Mabu crystalline klippe* with a Tibetan Tethys sediment cover. An extensive crystalline thrust sheet exists in the eastern Nepal Lesser Himalaya with a few tectonic Windows.

The *Kathmandu Nappe* was first recognized by Hagen (1969) and later mapped in detail by a number of workers. A narrow arm of this nappe making an outlying klippe forming the Mahabharat Range extends east ward for over 70 km before it joins with the main crystalline thrust sheet of the eastern Nepal. The thrust separating the crystalline rocks of the nappe from the underlying metasediments of Nawakot Complex is named as the Mahabharat Thrust in the south around Kathmandu, and is shown to be a direct continuation of the Main Central Thrust (MCT) of the north (Stocklin, 1980, Le Fort, 1989). The rocks of *Kathmandu Nappe* is grouped into the Kathmandu Complex which is subdivided into the lower Bhimphedi Group (about 10.5 km apparent thickness) of Late Precambrian age and the unconformably (?) overlying essentially a fossiliferous Lower Paleozoic sedimentary sequence of Phulchauki Group (3.5-4 km thick). In the south, southeastern and the southwestern parts of the Kathmandu Valley the Bhimphedi Group is represented by the garnet-schist, marble, quartzite and meta-basics. A number of granite bodies of various sizes are mapped within the Kathmandu Nappe.

The *Jajarkot Nappe* consists of muscovite-biotite schist and garnet-biotite muscovite schist with subordinate amount of micaceous quartzite,garnetiferous graphitic schists, and augen gneisses. Some smaller granitoid bodies occur within these rocks. It is also capped by the carbonate rocks of Lower Paleozoic age as in the Kathmandu Nappe. The *Bajhang Nappe* which is the direct extension of the *Chiplakot or Munsiari Nappe* of Kumaon consists of the phyllites and quartzites. The *Dadeldhura Nappe* which forms a large crystalline nappe in far western Nepal is also the direct continuation of the Almora Nappe of Kumaon. It consists of garnet-mica schist, graphitic schists, quartzites and granitic gneiss with a large granite body.

All the above mentioned crystalline nappes, except the crystalline thrust sheets of the eastern Nepal (east of Gaighat-Diktel section to the eastern border of Nepal) and the *Karnali Nappe* (*Chakhure-Mabu Crystalline Klippe* of Arita, 1984), are primarily composed of low (chlorite grade without biotite and garnet) to medium-grade (biotite and garnet with rarely kyanite) meta-sedimentary rocks along with metavolcanics and gneisses of granitic origin. In two areas (*Kathmandu and Jajarkot nappes*) these metamorphic sequences are capped by Lower Paleozoic low to non-metamorphosed rock sequences without a tectonic break. Invariably these nappes contain granite intrusions of widely varying sizes. The smaller bodies are normally highly sheared and converted into granitic gneisses. The granites are normally of Cambro-Ordovician age. The grade of metamorphism does not normally exceed the albite-epidote-almandine sub-facies of the green schist facies of regional metamorphism. Metamorphism is most often marked by chlorite+biotite or biotite+garnet assemblages. However, in Almora Nappe kyanite and staurolite have been reported along with occasional sillimanite mineral.

The Higher Himalayan Crystallines which are supposed to be the root zones of the Lesser Himalayan crystalline nappes variously named as the Central Crystallines and Vaikrita Group in Kumaon, Tibetan Slab and Himalayan Gneiss Zone in Nepal, represent a very thick pile (over 10 km in some sections) of high grade metamorphic rocks essentially consisting of very coarse grained kyanite-and locally sillimanite-bearing garnet-muscovite-biotite psammitic gneisses and schists. Kyanite which is normally abundant in these Higher Himalayan Crystallines is often a good marker of the base of the unit, although sometimes they are present in the Lesser Himalaya beneath the MCT. Sillimanite is abundant in the upper part especially when the total thickness of the rock sequence is greater.

A third group of rocks belonging to the MCT Zone has been variously interpreted as a separate tectonic unit bounded on both sides by thrusts (Valdiya, 1980, Arita, 1984, Fuchs, 1970) or as a continuous sequence belonging to the Upper Midland Formation of the Lesser Himalaya overridden at the top by the Tibetan Slab along the MCT (Le Fort, 1989). This zone has a higher grade of metamorphism than that of the Lower Midland rocks comparable to the metamorphic grades of the Lesser Himalayan crystalline nappes. Some authors regard this unit as the root zone of some of their Lesser Himalayan nappes (e.g. Munsiari Nappe, Valdiya, 1980; and Jajarkot Nappe, Arita, 1984) .

THE QUESTION OF ROOT ZONE

While consideringhe root zone of the *Kathmandu Nappe, Jajarkot Nappe, Bajhang Nappe* and the *Dadeldhura Nappe* in Nepal and similar nappes in the west in the Indian Himalaya, one must answer some of the fundamental questions. Are the metamorphic grades of the rocks of root zones and the nappes similar ? Are the lithology correlatable even very broadly ? Are the stratigraphies on both sides comparable ? Does the total thickness of the rocks of root zone corresponds well to the total thickness of the rock units in the nappes.

It is widely believed that the root zone of Kathmandu Nappe lies to the north in the Higher Himalayan Crystalline Zone (Tibetan Slab). Hagen (1969) even considered the Gosainkund area in the north of Kathmandu as the tectonic bridge between the nappe and the root zone. But the metamorphism found within the rocks of *Kathmandu Nappe* is low to medium grade which is in no way comparable to that found in the Tibetan Slab which has higher grade rocks like kyanite±sillimanite bearing gneisses and migmatites. No comparable 500 Ma cordierite bearing two-mica granites, so abundant in the nappes, are present in the Higher Himalayan Crystallines (they only contain Tertiary granites related to the Himalayan orogeny). Another striking point is the major difference in the stratigraphy and the lithology between the Kathmandu Nappe rocks and the so called root zone. Even the Phulchauki Group supposed to be the representative of the Tibetan Tethys Zone rocks within the nappe has no such striking similarity with its root zone.

So far no authors have put forward the idea that Kathmandu Nappe has its root in the Main Central Thrust Zone (MCT Zone) below the MCT as envisioned by Valdiya (1980) for the Almora and other Nappes in Kumaon (the Munsiari Formation as the root zone). Interestingly, Valdiya (1980) has not identified the Higher Himalayan crystallines (his Vaikrita Group) as root zones for any of his Lesser Himalayan crystalline nappes. The presence of the fossiliferous Phulchauki Group unconformably(?) overlying the metamorphics outrightly negates the possibility of the root zone of the *Kathmandu Nappe* in the MCT Zone. The difference between the thickness of the rocks of MCT Zone (2-3 km at most) and the Kathmandu Complex (over 14 km) also does not support their interrelationship.

In western Nepal the *Jajarkot Nappe* which has also the Lower Paleozoics of the Tibetan Tethys affinity as the capping on the metamorphics, its root zone has been placed in the MCT Zone (Arita, 1984). Here the lithology, metamorphic grade as well as the thickness of rock units in both the areas may be comparable, but the presence of the overlying Lower Paleozoic rules out the possibility of their past continuity. *Dadeldhura Nappe* which has so much similarities with the *Kathmandu Nappe* except the Lower Paleozoic cover, also faces the problems of its root zone. The MCT Zone (the Munsiari Formation of Valdiya) as well as the Higher Himalayan Crystallines can be ruled out as its root zone on the similar grounds as discussed above.

It may be pointed out that the present author agrees with Arita (1984) in that the root zone of the *Karnali Nappe* (*Chakhure-Mabu Klippe* of Arita) with its Tethyan cover lies in the Higher Himalayan Crystallines i.e. to the north of MCT. The extension of the Karnali Nappe must close westward much before Dadeldhura Bazar. In the eastern Nepal the author believes that the crystalline thrust sheet has covered most parts of the country and has reached near to the MBT.

Based on the above observations and the difficulties in accepting the Higher Himalayan Crystallines or the MCT Zone rocks as the root zone of the Lesser Himalayan crystalline nappes, the author suggests that the root zones of the above mentioned crystalline nappes are nowhere exposed in the north and that their rock assemblages including the Lower Paleozoic cover have no comparable counterparts. This implies that these nappes are the *exotic slices* in the Lesser Himalaya. The rocks of these nappes along with the Lower Paleozoic cover may represent the sediments deposited on the northern edge of the continental marginal sea at an intermediate position between the present Lesser Himalayan metasediments and the true Tibetan Tethys sediments of the north. Initially they were thrust to the south over the Lesser Himalayan metasediments, in front of but much to the south from the MCT, folded along with the underlying low grade rocks and preserved in the synclinal cores. The profuse granite intrusions of various ages in theses rocks may represent a special tectonic condition in that particular region of the basin which was lacking in the more proximal part of the continental margin. At present the root zones of these nappes may be found concealed beneath the MCT which was fast advancing to the south in its initial stage of development.

References

Arita, K., Shiraishi, K. and Hayashi, D., 1984. Geology of Western Nepal and a comparison with Kumaun, India. *Jr. Fac. Sci. Hokkaido Univ. Ser. IV, 1-20.*

Fuchs, W. and Frank, W. 1970. The geology of West Nepal between the rivers Kali Gandaki and Thulo Bheri. Jahrb. Geol. B.-A, Sonderband 18, Wein. 1-103p.

Hagen, T. , 1969. Report on the geological survey of Nepal, Vol. 1. *Denkschr. Schwez. Naturf. Gesell, Bd. 86, Hf. 1, 185p.*

Le Fort , 1989. The Himalayan orogenic segment. Tectonic evolution of the Tethyan region. *Ed. A.M.C. Sengor. Kluwer Academic Publishers, 259, 286-386.*

Stocklin, J., 1980. Geology of Nepal and its regional frame. *Jr. Geol. Soc. London., 137, 1-34.*

Valdiya, K.S. 1980. Geology of the Kumaun Lesser Himalaya, Wadia Institute of Himalayan Geology, 291p.

Isotopic Evidence of a Middle Proterozoic Orogeny From the Arunachal Lesser Himalaya (NEFA), India

RAO. S. PUNATI, R. FREI and JAN D. KRAMERS
Gruppe Isotopengeologie, Erlachstrasse 9a, Uni. Bern, Switzerland

Based on geological evidence Baig et al (1988) reported a late Proterozoic Cambrian orogeny from the Pakistan Himalaya. The search for direct isotopic evidence for tectono-metamorphism and orogeny either during the late Proterozoic or middle Proterozoic in the Himalaya, has been without success so far. Here we report the first direct isotopic evidence for a middle Proterozoic tectono-metamorphism, based on our multi isotopic study on the Bomdila basement gneisses from the Arunanchal Lesser Himalaya (NEFA).

The Arunanchal Lesser Himalaya is part of the Arunachal Himalaya, which is situated east of Bhutan. The basement gneisses are part of the Bomdila Group. The Lesser Himalaya in the Arunanchal mainly consists of the Bomdila Group of rocks, which is divided into Tenga, Dedza and Dirang Formations which all occur as schuppen or thrust sheets. The Tenga Formation is characterised by quartzite phyllite and altered mafic volcanic flows. The Dedza Formation (Riphean) conformably overlies the Tenga formation and consists of dolomite, dolomitic marble with a basal oligomictitic conglomerate. The Dirang formation has an unconformable contact with the underlying Dedza Formation and consists of garnet-biotite-muscovite-quartz schist, quartzite with minor phyllite and tremolite-actinolite marble. The Dirang Formation is thrust over by the Northern Sela belt with the high grade metamorphic rocks along the Main Central Thrust (MCT).

Petrographically the gneissic samples show quartz, potash and plagioclase feldspar and micas as the dominant mineral phases with sphene, zircon, apatite, sericite and epidote as minor phases. Alignment of micas forms the foliation. Geochemically the gneisses are peraluminous with calc-alkalic nature and are dominantly granite to Qtz diorites and monzogranites. These are orthogneisses with S-type geochemical character. They plot in the volcanic arc and collision granite fields of the Nb-Y discrimination diagram, signifying an active continental margin (Rao et al. in prep).

Two samples of the Bomdila orthogneisses have been dated using the conventional U-Pb zircon method. The U-Pb discordia of Ap-3 sample yields 1874±74 Ma as the upper intercept and 147±24 Ma as the lower intercept (2o) with MSWD 0.32. The upper intercept signifies the age of crystallization of the zircon and the lower intercept may not have any geological meaning but may be related to the Himalayan orogeny or quasi continuous lead loss. The AP-7 sample from the same suite but from about 15 km away from the AP-3 sample, yield U-Pb zircon ages 1827+95 as the upper intercept and 91±20 Ma as the lower intercept (2o) with MSWD 0.404. The ages are in agreement with other reported ages from the west of the belt, which proves that this is a widespread plutonism around 1800-1900 Ma.

The Pb-Yb data of the step leached titanite (after Frei and Kamber 1995) define a isochron yielding 1781±9 Ma (2o) with MSWD 1.1. This age of the titanite can be interpreted as dating the crystallization or formation of the titanite under amphibolite facies metamorphism. This tectono-etamorphis event converted the magmatic protoliths to muscovite-biotite gneisses. The strong association of titanite with the biotite in the foliation and almost absence of titanite in the thin section away from the foliation, is the clear indication for the tectono-metamorphic origin of the titanite.

The Rb/Sr whole rock -muscovite ages range from 1000-1685 Ma. These muscovite ages are interpreted as the mixing ages between the tectonometamorphic and other younger events. The 1685 Ma muscovite supports the titanite age, indicating a middle Proterozoic tectonometamorphism in these rocks. The biotite in these rocks gave negative age on the whole rock-mineral pair. The Sm-Nd analyses of the 1800-1900 Ma gneisses gave model ages around 2.6 Ga, indicating reworked Archean crust. Therefore the 1.8-1.9 Ga plutonic event is part of an orogenic episode in which this older Indian Cratonic material was reworked at least in the Arunachal Himalaya. It was followed by a tectonometamorphic event at 1781±9 Ma, which converted the magmatic protoliths into the muscovite-biotite gneisses. From the name of area we found the evidence of tectonometamorphism, we call this orogeny the "**Kameng Orogeny**" in the Himalaya. This orogeny is comparable to the Hudsonian-Eastern Ghat Orogeny which is widespread in the Eastern Ghat mobile belt of India.

Paleomagnetism of Oolitic Ironstone Bed in Hazara District, Northern Pakistan: Cretaceous-Tertiary Paleo-laterite in Northwestern Lesser Himalaya

M. YOSHIDA and M. N. AHMAD
Geoscience Laboratory, Geological Survey of Pakistan, Islamabad, Pakistan

Chamosite-berthierine-hematite type oolitic ironstone, the Langrial iron ore, is distributed in Hazara District, northwestern margin of Indo-Pakistan subcontinent which is situated in the northwestern part of the Lesser Himalayan belt. The ironstone bed is assumed to be a paleo-laterite formed during Cretaceous-Tertiary time. The oolitic ironstone bed induces a geomagnetic anomaly with a maximum anomalous intensity of c.300nT; and no meaningful anomaly pattern was observed by VLF-EM survey. The oolitic ironstone shows rather small magnetic susceptibility and relative weak NRM intensity but very hard coercivity. Ferromagnetic properties of the rock are mainly derived from hematite grains which possesse two remanence component: the overprint component (Declination=83.6∞, Inclination=27.7∞) and the characteristic remanence component (Declination=298.5∞, Inclination=19.8∞). The characteristic component probably indicates paleomagnetic direction during the formation of oolitic ironstone which is inferred to be a lateritization process in Cretaceous-Tertiary (K-T) boundary time. The overprint component which passed a reversal test was possibly a thermo-viscous remanent magnetization (TVRM) acquired by long-term burial heating due to a down-thrusting of the terrain. The overprint remanence direction suggests a presence of clockwise rotation of the terrain after the acquisition of overprint component.

The Structure of the Nepalese Himalayas as Derived from Satellite Imagery

P. HOPPE
BGR, Hannover, Germany.

The synoptic view over large areas provided by satellite images shows general or detail tectonic structures within different areas of the Himalayas. Some of these images presented here reflect the younger history of the Himalayan mountain building. The Himalayas in Nepal are subdivided mainly into four tectonic units which are from south to north the alluvial Gangetic Plain, the Tertiary-Quaternary Siwalik Group, the Lesser Himalaya Unit and the Higher Himalaya Unit both of them built up by Precambrian to Paleozoic/Mesozoic rocks. Also, these tectonic units form in general the geographical units within the Nepalese Himalayas. The boundary between the Gangetic Plain alluvium and the Siwalik Group sediments is sedimentary or thrusted by smaller thrusts, called Main Frontal Thrust (M.F.T.). The boundary between the Siwalik Group and the Lesser Himalaya Unit is formed by the deep rooted Main Boundary Thrust (M.B.T.) and the accompanying small and normal Main Boundary Active Fault. Between the Lesser Himalaya and Higher Himalaya Unit there is the nappe base of the Higher Himalayan Crystalline, which is called the Main Central Thrust (M.C.T.). It is more or less following the boundary between the geographical units, Lesser Himalaya and Higher Himalaya. But also within the geographical unit Lesser Himalaya, large areas of Higher Himalayan Crystalline float thrusted on top of the Lesser Himalaya rock unit separated by the southern continuation of the Main Central Thrust, mainly

no named or locally called Mahabharat Thrust south of Kathmandu. M.B.T. and M.C.T. are long reaching thrusts directed towards the south. They are one result of the subduction of the Indian Plate underneath the Asian Plate. Another result is block faulting and lateral/oblique movements cutting through the stapled Himalayan rock units. The satellite images presented here are mainly delivered from the US American LANDSAT Thematic Mapper multispectral scanning system. Some images are from the Indian Remote Sensing Satellite IRS-1, from the French multispectral scanner system SPOT, the European Remote Sensing Satellite radar system AMI/SAR, the German Metric Camera and the multispectral MOMS system, and from the Russian multispectral camera MK-4. The images are mostly used by the staff of Department of Mines and Geology, Kathmandu and of the German Geological Advisory Group at this department as base of geological photo-interpretation, and scientific and logistic plannings of the field trips.

Regional Geology and Lineament Analysis of the Area Around Barwah, Lower Narmada Valley Region, M. P., India,Through Remote Sensing Technique

R. S. RAGHUWANSHI

M.V.A.M., Bhopal, M.P., India

and

K. K. RAO

Department of Applied Geology, Barkatullah University, Bhopal

The Narmada valley region consists of the outcrops of various rock types ranging from Archaeans to Recent with wide compositional variations and varied structural features. To understand the above facts geological and lineament maps of the area around Barwah in the Lower Narmada valley region have been prepared using LANDSAT-4 MSS (multi-spectral scanner) FCC data, on a scale of 1:250,000. A detailed study of the geology reveals that the area of present investigation comprises of lava flows of Deccan Trap igneous activity in the north, west and southern parts. The rocks belong to Vindhyan Supergroup lying in the eastern part of the area. Apart from these, the other lithological formations like Bijawars, Lametas, Baghs and metamorphics are also exposed as small outcrops in the study area. The detailed study of the plotted roset of the data shows that the frequency of lineament in the region is maximum in ENE-WSW direction and the length of the lineaments is also extensive in the ENE-WSW direction. The study of the lineament fabric further reveals the presence of two more sets of lineament in NW-SE and WNW-ESE directions. On the basis of aforesaid studies it may be mentioned here that the ENE-WSW and NW-SE predominating trends in the region most probably reflect that these lineament trends were present right from the development of proto-continents at the time of formation of Indian Peninsular Crust, while the WNW-ESE trend most probably related to the origin of Narmada-Son geo-fracture during comparatively later period. These crustal lineaments might have been activated again and again during different periods in the geological history and have certainly influenced and controlled the sedimentary and tectonic history of the region.

Evaluation of Remote Sensing and GIS Techniques for Geological Studies in Western Part of Doon Valley

R. CHANDRA
Wadia Institute of Himalayan Geology, Dehradun

A. K. SINHA
Dept. of Geology, Univ. of Rajasthan, Jaipur
and
D. K. JURGAN
Indian Institute of Remote Sensing, Dehradun, India.

The western part of Doon Valley in Uttar Pradesh and Himachal Pradesh were studied to evaluate the Remote Sensing and GIS Techniques as a comparative study for Geological Mapping along with selective field checks. Black and white Panchromatic Aerial Photographs and LANDSAT-MSS and TM-FCC were used to delineate nine Geological units i.e. Pre-Tertiary, Subathu, Lower Siwalik, Middle Siwalik, Upper Siwalik, Old Doon Gravel, Doon Fan Gravel, Sub-Recent Fan Terrace and Alluvium, geological structures like folds, faults, joints etc., major trends of lineaments and Neo-tectonic activity. LANDSAT-TM-CCT was used for generating digitally enhanced false color composite, Principal component analysis, Band Ratio images and Filtered products for better correlation. The rock types are mainly Quartzite, Phyllite, Slate, Limestone, Sandstone, Shale, Conglomerate, Older and Newer Alluvium. Aerial Photo-Interpretation is best alternative for large scale mapping, LANDSAT-TM-FCC for small scale mapping and digital image processing of LANDSAT-TM-CCT has increased the inter-pretability of geological features. The present study has established the applicability of optical and infrared Remote Sensing Data for a better perspective of geological investigation. An attempt has been made to utilize the capability of ARC/INFO GIS Package for generation "Geological Map" of the study area.

Strain Analysis of Gash Veins of Devprayag Area,Garhwal Himalaya

S. GUHA and P. S. SAKLANI
Department of Geology, University of Delhi, Delhi, India

Gash veins are openings which are commonly developed adjacent to the faults, oriented at about 45° to the direction of simple shear and perpendicular to the direction of maximum extension. They are usually arranged in en-echelon pattern along the plane of shear zone. In the present study the strain pattern is determined by the analysis of these veins, between Kauriyala to Devprayag in the Lesser Himalaya of Garhwal region of Uttar Pradesh. The area is constituted of Saknidhar (Nagthat) quartzite and Pauri phyllite and is located between 78°30'E - 78°40'E longitudes and 30°2'N-30°10'N latitudes. The major tectonic features present in the area are North Almora Thrust, Kauriyala Fault and Devprayag Fault.Gash veins are important strain markers. They show varied pattern viz. sigmoidal, non-sigmoidal and are developed mostly in the Saknidhar quartzite. Concentration of these veins are of localized nature.

The orientation of Reidel (R_1 R_2), transitional and extensional types of veins of sigmoidal and non-sigmoidal pattern, gives a clear picture of strain distribution in the area and it can be concluded that the formation of these veins was mainly controlled by the major tectonic structures.

Application of Mathematical and Computer Techniques in Geothermobarometry of Some Himalayan Granites

T. N. JOWHAR
Wadia Institute of Himalayan Geology
Dehra Dun, India.

Estimation of equilibrium temperatures and pressures of various coexisting minerals in igneous and metamorphic rocks is important from the petrogenetic aspects. In this paper the importance of mathematical and computer techniques in the solution for estimation of P and T is stressed. A FORTRAN 77 computer program is discussed for calculating enthalpy, entropy and Gibbs free energy of minerals at higher temperatures and pressures from their thermodynamic data at 298.15 K and 1 bar. Application of numerical methods for solution of non-linear geothermobarometric equations is presented. Two examples are discussed, one from Higher Himalayan tourmaline granite from Badrinath and the other from Trans-Himalayan Ladakh batholith.

Thermodynamic data on alkali feldspar-muscovite is utilized to solve total exchange potential of K-Na exchange between the mineral pair. This leads to the estimation of equilibrium temperature. An application of this geothermometer was carried out on the alkali feldspar-muscovite from three rock unit of the Bardrinath Crystalline Complex, viz., feldspar gneiss, Badrinath granite and associated pegmatites. The published geological and radiometric data indicates that the country rock (feldspar gneiss), a Precambrian unit, was intruded by the Badrinath granite around 20 Ma ago. Temperature estimates by alkali feldspar-muscovite geothermometer, however, are in the neighbourhood of 500°C for the country rock as well as the intrusive. These temperature values are significantly lower than the melt-crystal equilibrium for a muscovite granite. It implies that there was a post-granite emplacement thermal event during which temperature got stabilized to a lower value causing equilibration of K-Na exchange between alkali feldspar and muscovite.

Estimation of pressure of crystallization of Ladakh granites (samples from Khardung La, altitude 5440 m above msl) has been carried out by using hornblende geobarometer. Pressure of crystallization has been calculated to be 2.7 ± 0.6 kbar, which implies that these granites solidified at a depth of 9.2 ± 2 km. Thus, these geobarometric results on Ladakh granites from Khardung La constrain that there has been 9.2 ± 2 km of unroofing in this region.

Metamorphic Evolution of the Central Crystallines of Higher Himalaya in Dhauli Ganga Valley, Garhwal Himalaya, India

S. P. SINGH
Dept. of Geology, H.N.B. Garhwal University,
Srinagar, U.P., India

V. K. SINGH and P. S. SAKLANI
Department of Geology, University of Delhi, Delhi, India

The Central Crystallines (=Vaikrita Group) of Higher Himalaya in the valley of the Dhauli Ganga of the Garhwal Himalaya is tectonically delineated by a northward dipping Vaikrita Thrust. It also separates Munsiari (=Jutogh) Group of rocks in south while its tectonic boundary in north is the Tethys Fault/Thrust. The crystallines comprises granitoids, gneisses, migmatites and metamorphics. The Tertiary leucogranite occurs as small patches in the upper Central Crystallines and have extensive intrusion around Malari village near the Tethys Fault/Thrust.

The rocks of this zone are polyphase deformed. The critical metamorphic assemblage obtained from detailed textural studies from the pelitic, psammitic, calcareous and basic rocks of Central Crystallines have witness of three episodes of metamorphism viz. M_1, M_2 and M_3.

The regional metamorphism M_1 is medium to high grade which have the critical assemblages viz. Mus±Gt-Ky±Plag-Bio-K-feld-Qtz, Gt-Sill±Ky-Mus-K-feld-Bio±Plag-Qtz, Sill-K-feld ±Gt+ Cord-Plag-Qtz from pelitic rocks correspond to the Kyanite-Muscovite, Sillimanite-Muscovite, and Sillimanite-Orthoclase subfacies of amphibolite facies. The reaction isograde:

Ky == Sill ----------------------- (1)
Mus+Qtz == K-feld+Sill+V --- (2)
Bio+Sill+Qtz == Cord + V -- --(3)

have been noticed from the pelitic rocks at various places in the Dhauli Ganga valley.

The detailed structural studies and presence of mylonite, repetition of reaction isograd (1), (2) and (3) suggest a deformation after the M_1 episode of metamorphism. During this deformation, low to medium grade rocks were developed which have high angle dip but in same direction northward. These low to medium grade rocks formed during M_2 metamorphic episode have critical assemblage of Gt-Chl-Mus-Qtz-K-feld, Bio-Chl-Mus±Ky-Qtz and Alm±St-Mt-Ky-Mus-Bio-Qtz. The rocks of these assemblages are usually 100±50 m thick and occur within the ±Ky-Sill-Mus, Sill-Mus-K-feld and Sill-K-feld zones of upper amphibolite facies of M_1 metamorphic episode.

The most interesting feature of these two different metamorphic grade are clearly preserved in garnet. The garnet of M_1 episode are medium grained, highly fractures, devoid of rotation and absence of xenoblastic chlorite and coarse grained magnetite inclusion, but occasionally contains the inclusion of small grains of kyanite, biotite and magnetite minerals. The xenoblastic garnets of M_2 episode are coarse grained, mostly rotated type or post-crystalline in nature and contains the inclusions of magnetite, chlorite and quartz. These M_2 garnets are usually present in the contact of biotite.

The M_3 episode of metamorphism is characterised by low-grade dynamic metamorphism and is confined only in the shear and mylonitised zone. The chloritisation of garnet and biotite, the post-tectonic growth viz. polygonal mortar structure of quartz are frequent. The Chl-Bio-Mus-Qtz, Ser-Bio-Ctd-Mt-Qtz, Plag-Ep-Tre-Cal-Qtz, And-Chl-Grap-Ser-Qtz are some typical assemblage of this zone.

The P-T conditions based on various experimental curves evaluate that the Central Crystallines experienced 700-800^{o}C/6-8 Kbar during M_1 episode, 500-600^{o}C/5-6 Kbar during M_2 and 400-300^{o}C less than 4 Kbar pressure during M_3 episode of metamorphism.

Alkali Feldspars from the Badrinath Crystalline Complex and Their Bearing on the Himalayan Metamorphism

T. N. JOWHAR
Wadia Institute of Himalayan Geology, Dehra Dun, India
and
P. K. VERMA
Department of Geology, University of Delhi, Delhi, India

The Badrinath Crystalline Complex is a part of the Central Crystallines along the Himalayan axis. Feldspar gneisses are important constituents of this complex and are intruded by a post-tectonic tourmaline-bearing granite. Alkali feldspars from the host rock, granite and associated pegmatites were studied. A high degree of Al-Si ordering in them from all the three units were found. All samples indicate ideal one-step ordering. It is proposed that a low grade regional metamorphism subsequent to intrusion prevailed in the Central Crystallines of the Himalaya.

The Granitoids of Central Crystallines and Lesser Himalayan Nappes: Petrogenetic and Tectonic Aspects

L.S. CHAMYAL and M. KAUR
Department of Geology, M.S. University of Baroda, Baroda, India.

The study mainly dwells upon the evolution of the granitoid rocks which comprise the dominant rock types of the Central Crystallines. Attempts are made to compare and contrast them with the granitoids of the Lesser Himalayan Crystalline Nappes which are supposed to be the southern counterparts of the Central Crystallines.

North Delhi Fold Belt Granitoids : Their Characteristics in Relation to Possible Tungsten Mineralization

M.K. PANDIT
Dept. of Geology, University of Rajasthan, Jaipur, India
and
S. BANERJI
B-60, Malviya Nagar, Jaipur 302 017, India

The state of Rajasthan in western India exposes rock types ranging from the oldest Archaean to Recent alluvium/wind blown sand and contains two well defined Proterozoic fold belts, the Early Proterozoic Aravalli and the Middle to Late Proterozoic Delhi Fold Belt. These fold belts have proved to be useful sites for understanding the crustal evolution process and to identify the target areas for a particular mineral search.

The strategic importance of tungsten warrants urgent steps for new discoveries of this valuable metal. The known workable deposits of tungsten are located in western India in association with the Post-Delhi polyphase silicic intrusives and volcanics belonging to Erinpura and Malani Volcanic Suite. All the incidence.occurrences of tungsten mineralization associated with the Delhi Granitoids are located within the South Delhi Fold Belt. The litho-assemblages, geological setting and emplacement of granitoids have been recognized as the controlling factors for tungsten mineralization.

Similar rock assemblages along with a number of granitoid and migmatite bodies have been located within the North Delhi Fold Belt. The region though with comparable geological factors has remained neglected so far in relation to South Delhi Fold Belt. Since there is no unique origin and chemical characteristics no general agreement could be arrived at to work out a uniform exploration strategy as the mineralization is governed by a number of regional phenomena and local factors. Certain distinguishable geochemical parameters can, however, be utilized to diagnose the capability of a granite in terms of its association with specific minerals. In the present work a number of granitoid bodies have been studied from North Delhi Fold Belt to identify and delineate the target areas for detailed exploration for tungsten mineralization on the basis of certain parameters established for the South Delhi Fold Belt.

Petrogenesis of Ajitgarh Granitoids from Part of North Delhi Fold Belt, Rajasthan, India

M. KHATATNEH and M. K. PANDIT
Department of Geology, University of Rajasthan, Jaipur, India.

The rocks of Delhi Supergroup forming an important tectono-stratigraphic unit of the Aravalli mountain are characterized by syn-sedimentational volcanics and polyphase intrusives (Erinpura granite).

The Delhi sediments are highly deformed and three phases of deformation have been recognised besides two metamorphic events as evidenced by the microtextural characters. The rocks of Delhi Supergroup have been divided into two fold belts, the North Delhi Fold Belt (NDFB) and the South Delhi Fold Belt (SDFB). The NDFB is further subdivided into three depositional basins.

The area of present investigation around Ajitgarh forms a part of Alwar basin in northeastern Rajasthan. The area is characterized by granite-tonalite assemblage representing an intrusive phase of acid magmatism. These have been intersected by tourmaline bearing pegmatites showing a bimodal distribution. The relationship between the granite and the metasediments is not clear due to alluvium cover.

The Ajitgarh pluton comprises of two types of massive non-foliated granite, pink granite and grey granodiorite. The chemical characteristics show both I and S type signatures. The magmatic activity in the region appears to be coeval with the DF2 deformation with characteristic absence of foliation and penetrative schistosity. The granodiorite and granite appear to represent two different phases of magmatism possibly attributed to the difference in the levels of partial melting of the crust in generating the liquids.

Geology and Petrogenetic Implications of Bambholai Bimodal Volcanic Suite, District Pall, Western Rajasthan, India

R. SAXENA and M. K. PANDIT
Department of Geology, University of Rajasthan, Jaipur, India.

The rocks of Delhi Supergroup in the northwestern India represent a very important tectono-sedimentary unit. A number of magmatic episodes ranging from syn-sedimentary volcanic sequences to acid intrusives are reported to be associated with the Delhi Sediments. Volcanic episodes are recognised at two distinct stratigraphic levels, one within Railo Group and the other within Ajabgarh Group.

The area of present investigation around Bambholai (25^{o} 51'30" N : 73^{o} 23'20" E) in district Pali, western Rajasthan exhibits widely manifested syn-sedimentational bimodal volcanism. The area is predominantly composed of pillow lavas exposed between Punagarh and Khamal in a peneplained terrain dotted with small hills. The phyllites and quartzites represent the sedimentary assemblage and basalt-rhyolite represent the volcanic component. The whole sequence is further intruded by granites of Erinpura age. In Bambholai area three basaltic flows have been delineated on the basis of interflow sediments. The Bambholai hill and the adjacent area to its east and south display well developed pillow breccia. The size and shape of pillows vary widely with radial jointing as a common feature. Vesicles and amygdales are usually filled with calcite, quartz and zeolite. The pillow basalt is composed of olivine, plagioclase, clinopyroxene, glass, iron oxides and secondary quartz. The basaltic flows show large scale elemental variation both within and between flows and appear to be cogenetic with the rhyolitic rocks of the area. The intrusive granites of Erinpura age and the Malani volcanics post date the volcano-sedimentary sequence and represent separate phases of acid magmatism in the area.

Petrology of the Doda District Granites, Jammu Lesser Himalaya

B. L. DHAR, A. K. RAINA and B. K. FOTEDAR
Post Graduate Department of Geology, University of Jammu, Jammu, India

Granitic rocks in Doda district of Jammu and Kashmir State, NW Himalaya are exposed at eight places having intrusive relationship with the Precambrian older metamorphics. These have been termed Dramman-, Piparan-, Kaplas-, Khol Dedni-, Chinta-, Bhala-, Kal Nala- and Nagin Dhar- Granites and occur in the form of irregular linear bodies of varying outcrop widths, some assuming batholithic dimensions. The granites are mostly leucocratic, two mica, aplitic to porphyritic, massive and highly jointed with crude foliation in some cases. In all the cases the contact with the older metamorphics is sharp but distinct thermal aureole is absent. The granites show following distinct petrological characters:

a. These are Monzo- to Syeno- granitic in composition,
b. These are of peraluminous character, S-type equivalent to ilmenite series and possess calc-alkaline affinity.
c. These are emplaced within the older metamorphics under tectonic influences at later stages of metamorphism with the magmatism as a result of crustal thickening.
d. These are highly evolved anatectic granites derived by the partial melting of the lower crustal material with diapiric situations.
e. The process of anatexis of metasedimentary precursor rocks has been operative at a temperature of 600-700°C at a depth of 20-30 km under 5 Kb pressure.
f. The emplacement of these granites is suggested to be due to transient dilation where the diapir is enhanced by sheeting mechanism.

Geochemistry of Dyke Rocks of Deccan Trap Region Around Manmad, District-Nasik, Maharashtra, Inida

P. K. JAIN
School of Studies in Earth Science, Jiwaji University, Gwalior, M.P., India
and
D. C. GUPTA
Department of Applied Geology, Barkatullah University, Bhopal, M.P., India.

The present paper deals with the geochemistry of Manmad dyke rocks on the basis of their major, trace and rare earth elements (REE) concentration in the rocks for the first time.

Three doleritic dykes namely - Ankaiwari, Anakwade and Tankai-Ankai are exposed in the field. Major oxides, twenty four trace elements (including Pb, Zn, Ni, Co, Cr, Rb, Ba, Sr. and Y) and seven REE namely La, Ce, Eu, Gd, Tb, Yb and Lu have been analysed by various techniques. Normative composition suggests olivine bearing and olivine free dykes. Kuno's modified total alkalies and silica diagram suggests high K-tholeiitic nature of rocks indicating that the dykes magma was not derived from the deeper level of the crust. TiO_2 content of the dykes indicating low Ti-tholeiitic as proposed by Hergt et al. (1991). Depleted and increasing values of trace and rare earth elements in the rocks suggest fractionated nature and that these dyke rocks are relatively younger than the lava-flows of the area.

Thermoluminescence Emission in Natural Fluorites From Gore-Nawadih Mines, Palamau District, Bihar, India

D. SENGUPTA, S. SONI and A. B. MUKHERJEE
Department of Geology & Geophysics, I.I.T. Kharagpur, India.

Fluorite samples from Gore-Nawadih magnetite mines in the Palamau district in Bihar have been studied based on their luminescence emission, using Thermoluminescence (TL). In order to understand the nature of coloration and their association with impurity centres responsible for coloration, quantitative determination of the rare earths has also been made. The TL studies revealed a close conformity with the grain size and the abundance of the fluorites as compared to the associated minerals in these deposits. This in turn, seems to be correlated with the rare earth enrichment in the fluorites which result in their luminescence emission. The present study is useful in understanding the TL characteristics of natural fluorites, which could be gainfully employed in applications like radiation dosimetry and in establishing the geochronology of host rocks.

Nature and Genesis of Anorthosites of Type Areas with Reference to the Thermometry of Two-Pyroxene Granulites of Sittampundi Complex, Tamil Nadu

S. MITRA
Department of Geological Sciences, Jadavpur University, Calcutta

The mineralogical and geochemical distinctiveness of Archean and Proterozoic anorthosites of the world is delineated in the early part of this work before embarking on evaluating the thermal characters from the blocking and crystallization temperatures of the granulites of Sittampundi from two-pyroxenes. The orthopyroxenes of bronzitic or hypersthene varieties and clinopyroxene of two-pyroxene granulites (clinopyroxene + orthopyroxene + hornblende + garnet + plagioclase + carbonate) of Sittampundi complex compositionally lie in the granulite field of metamorphism. Mossbauer parameters of two-pyroxene granulites show that Fe^{3+} is restricted at the M1 site, and Fe^{2+} is distributed between the three different M1, m2 ($3R^{2+}$) and M2 (R^{2+}, R^{3+}) sites. The entry of Fe^{3+} in the regular M1 site maybe related to their formation at high aluminous environment and/or at high oxidising condition. The Mossbauer parameters of clinopyroxenes show that Fe^{3+} is restricted mainly at the M1 site, but tetrahedral Fe^{3+} is present in clynopyroxene (sample 5); the Fe^{2+} is distributed between M1 nd M2 sites. The metamorphic temperatures of two-pyroxene granulites determined by the Fe^{2+}-Mg distribution in associated clinopyroxene and orthopyroxene are 874-911°C (sample 5), 773 - 953°C (samle 6a) and 662°C (sample 13). From the distribution of Fe^{3+} and Fe^{2+} at different octahedral sites of orthopyroxenes blocking temperature of intracrystalline ordering of Fe^{2+} -Mg at M1 and M2 sites are obtained as 633°C (sample 5) and 427°C (sample 6a). The intracrystalline ordering of Fe2+-Mg over M1 and M2 sites records some lower temperature (241°C for sample 5 and 346oC for sample 6a) than the temperature obtained from intracrystalline distribution of Fe^{2+}-Mg between orthopyroxene and clinopyroxene. The lowering of blocking temperature suggests that cation ordering at M1 and M2 sites continued in the cooling path of the two-pyroxene granulites beyond the temperature indicated by the intercrystalline distribution.

Deposition and Diagenesis of Kawagarh Formation at Changla Gali, Muree-Ayubia Road, Hazara, Pakistan

N. AHSAN
Building Research Station, Near New Campus, Lahore
M. A. IQBAL
University of Oslo, Norway
and
M. N. CHAUDHRY
Institute of Geology, University of the Punjab, Lahore

A field and petrographic study of Kawagarh Formation from Changla Gali was carried out in order to work out microfacies, environment of deposition and diagenesis. The formation has been divided into 30 microfacies. They include dolomitic arenaceous mudstone, packstone, dolomitic packstone, dolospar and wackestone with occasional intercalated marls. These microfacies are grouped into four units from bottom to top.

The CU-I was laid down on top of Lumshiwal Formation in upper subtidal zone probably at a depth of about 50 to 80 m. The CU-II marks the rapid transgression and was deposited under pelagic shelf conditions below upper subtidal zone. This was followed by a CU-III sequence of wackestone to packstone with marly intercalations deposited in lower subtidal zone. CU-IV marks on-set of regression culminating into sub-aerial exposure.

Post depositional changes such as cementation, neomorphism, compaction, dolomitization and dedolomitization are discussed. Dolomitization owes to Mg^{+2} bearing solutions from underlying Chichali Formation.

Jurassic Shelf Sedimentation and Sequence Stratigraphy in the Surghar Range, Pakistan

S. AHMED
Institute of Geology, University of the Punjab, Quaid-e-Azam Campus, Lahore, Pakistan.
and
D. MERTMANN
FR Allgemeine Geologie, Freie Universitat Berlin,, Berlin, Germany.

In the Surghar Range, facies and biostratigraphical analysis of Jurassic platform carbonates shows that platform development was affected by both the variations in sea-level and the influences of a nearby hinterland. The well exposed shallow marine platform sediments of the Shinawari Formation and the Samana Suk Formation were deposited during the Toarcian up to the Middle Callovian. Their thickness attains about 175 m.

A rise in sea-level during the lower Toarcian brought about the submergence of the area which was a delta plain before. Shallowing upward cycles and smaller-scale paracycles are characteristic for the marine sequence. Relative seal-level lowstands occurred during the Bajocian, the Bathonian and the Lower Callovian. The lower two coincide with terrigenous influx from the southeast. The upper one is associated with a well developed hard ground. They are overlain by deposits of transgressive and highstand system tracts. The Jurassic shallow marine platform development ended with an omission surface. Drowning of the platform is indicated by the overlying deeper shelf deposits of the Oxfordian - Neocomian Chichali Formation.

Source Rock Composition of the Tipam Sandstone of Naginimara Area (Nagaland) as Revealed by Heavy Mineral Association and Petrography

T. KATAKI and D. MAJUMDAR
Department of Applied Geology, Dibrugarh University, Assam, India.

Heavy mineral association, grain morphology and petrography of Tipam Sandstones of Naginimara (Nagaland) were examined to evaluate source rock composition in the source area. A higher percentage of zircon (8.37-26.6%), garnet (14.18-43.78%), Chlorite (5.52 - 19.53%) and opaque minerals (9.73-26.6%) and lesser concentration of staurolite, tourmaline, rutile and hornblende characterizes the sandstones. Petrographic analyses reveal the existence of an association of various types with different angularity of quartz such as fractured, undulose, composite and quartz with varied orientation of pressure lamellae. Besides quartz, schistose and quartzitic fragments are found in the rocks. A predominance of rounded minerals over angular have been observed. Characteristic heavy mineral assemblage and petrographic composition suggest that the source area was primarily composed of sedimentary rocks with minor amounts of acid intrusives and metamorphic rocks.

Environment of Deposition of the Sandstones of Lower Vindhyans of Parts of Durg District, Madhya Pradesh, India

M. CHANDRA
School of Studies in Earth Science, Jiwaji University, Gwalior, India.

B. B. S. SINGHAL and A. K. AWASTHI
Dept. of Earth Science, University of Roorkee, Roorkee, India.

Present paper is an attempt to work out the environment of deposition of sedimentary formation, namely, sandstone of the Chhattisgarh Supergroup of lower Vindhyan age exposed in parts of Durg District, Madhya Pradesh (India).

Lithostratigraphic studies and palaeocurrent analyses of the sandstones were carried out. Two distinct environments of deposition, namely, braided fluvial and beach, have been interpreted for these sediments. The palaeocurrents are towards north, northeast and southeast.

Grain size and shape analyses of the sandstones have also been carried out. Vertical variations of the different grain size statistics of the fluvial and beach sediments have also been studied. A multivariate linear discriminant technique was adopted for discriminating the sediments of these two environments.

Petrographic studies and provenance analysis of the sandstones were carried out. Sandstones of the beach environment appear to be richer in quartz and poorer in matrix as compared to the fluvial ones. The sandstones of two distinct environments, viz., fluvial and beach, have been clearly differentiated with the help of multivariate discriminant analysis using thin section modal constituents like quartz, feldspars, iron oxide, matrix etc.

Results of all these studies, namely, lithostratigraphic, grain size and petrographic, fairly tally with each other thereby suggesting that the sandstones under study were deposited under two different environments, viz., fluvial and beach.

Sedimentology, Depositional Environment and Economic Potential of Datta Formation of Early Jurassic Age of Attock Hazara Fold and Thrust Belt

M. NAWAZ Ch., M. GHAZANFAR, I. H. BALOCH, M. ADIL
N. AHSAN and F. A. CHUHAN
Institute of Geology, Punjab University, Lahore, Pakistan

Datta Formation of Early Jurassic age is an important unit of Attock-Hazara Fold and Thrust Belt (AHFTB). This formation shows a profound variation both vertically as well as laterally in lithology and depositional environments. The depositional environment ranges from continental, supratidal, intertidal and upper subtidal.
The basal part of the unit, in Galiat part of the Hazara area, lies over the Hazara Formation of Eo-Cambrian age and is composed of sublithic arenites. The rock fragments are of the underlying slates and were reworked during early Jurassic transgression.

The overlying package is composed predominantly of lenses, sheets and layers of gritty, poorly sorted, texturally submature, compositionally mature, medium to coarse grained carbonate and quartz cemented quartz arenites and fine to very fine grained mainly quartz but also carbonate cemented quartz arenites. The latter are well sorted and texturally as well as compositionally mature.

The dominantly quartzose package also contains lenses of carbonaceous shales, silty shales, marls and oolitic and pelletoidal limestone. The package also contains hard ground surfaces marking diastems.

The package of Hazara area represents deposition along an unstable mixed siliciclastic-carbonate shelf depositional environment. The package here is predominantly marine as is evident from the presence of marine fauna, sedimentary textures, structures and rock body geometries.

The diagenetic events of the rock package in Hazara area have been discussed in relation to the burial and uplift history of the basin. Kaolinite and thin rim quartz cements were the first to form at shallow depths in the domain of meteoric or mixed meteoric-marine water circulation. This was followed, at greater depth, under alkaline and mildly reducing conditions by the precipitation of ferroan calcite. Transformation of kaolinite to illite probably started at around 1000 m depth. Extensive quartz cementation, suturing and reduction in porosity started at greater depth and was completed at depths of 4000 - 4200 m at which main phase of oil and gas maturation was completed.

Tourmaline, zircon, sphene and epidote constitute a very restricted suite of heavy minerals. This suite indicates derivation from S-type granitoids and low grade metasediments with metabasite component.

To the west of Hazara in Attock region of AHFTB the Datta Formation is composed predominantly of continental residual deposits. The lower part of the formation is a thin and discontinuous lateritic horizon, the middle part (which is the thickest) is composed of bauxitic clays while the upper part is composed of variegated sandstone and shale of continental to transitional maring origin.

The bauxitic clays which should in fact be called fire clays and high alumine clays are composed essentially of kaolinite, diaspore and boehmite. The accessories include rutile, anatase, quartz and chlorite.

Datta Formation is a possible minor source rock in Hazara area and a reservoir rock in parts of upper Indus basin. It is a very important source of silica sand, fire clay, pottery clay and high alumina clays. It is also a potential source of titana.

The Foraminiferal Genus Ranikothalia Caudri, 1944

S. J. SAMEENI and A. A. BUTT
Institute of Geology, Punjab University, Lahore, Pakistan.

The foraminiferal genus *Ranikothalia* (type species *Nummulites nuttalli* Davies, a typical nummulitid form having *Nummulites*) was erected by Caudri (1944). *Nummulites nuttalli* was, however, transferred to the genus *Ranikothalia* by virtue of its fan-shaped marginal cord which was taken as a typical character for the generic distinction. *Operculina sindensis* Davies, though an operculine complanate shell without septal filaments, was also included in the genus *Ranikothalia* on the basis of fan-shaped marginal cord.

The foraminiferal genus *Ranikothalia*, at present, includes either nummulitid form such as *Ranikothalia nuttalli* (DAVIES), or operculinid complanate types such as *Ranikothalia sindensis* (DAVIES) as well as intergrading species from initial nummulitid growth and ultimately becoming operculine such as *Ranikothalia sahnii* DAVIES (Butt, 1991). These different morphotypes are newly recorded from the Lower Eocene Margala Hill Limestone (a stratigraphic equivalent of the Sakesar Limestone of the Salt Range), Lora-Maqsood Road, Hazara Mountains, Northern Pakistan in association with other foraminiferal fauna (Plate I).

Although the foraminiferal genus *Ranikothalia* is characteristic of the Upper Paleocene shallow water deposits in various parts of the world, its rare presence in the Lower Eocene succession is also evident.

Future research activity is certainly needed towards the taxonomic details of the genus *Ranikothalia* because, at present, different morphotypes are included in this genus.

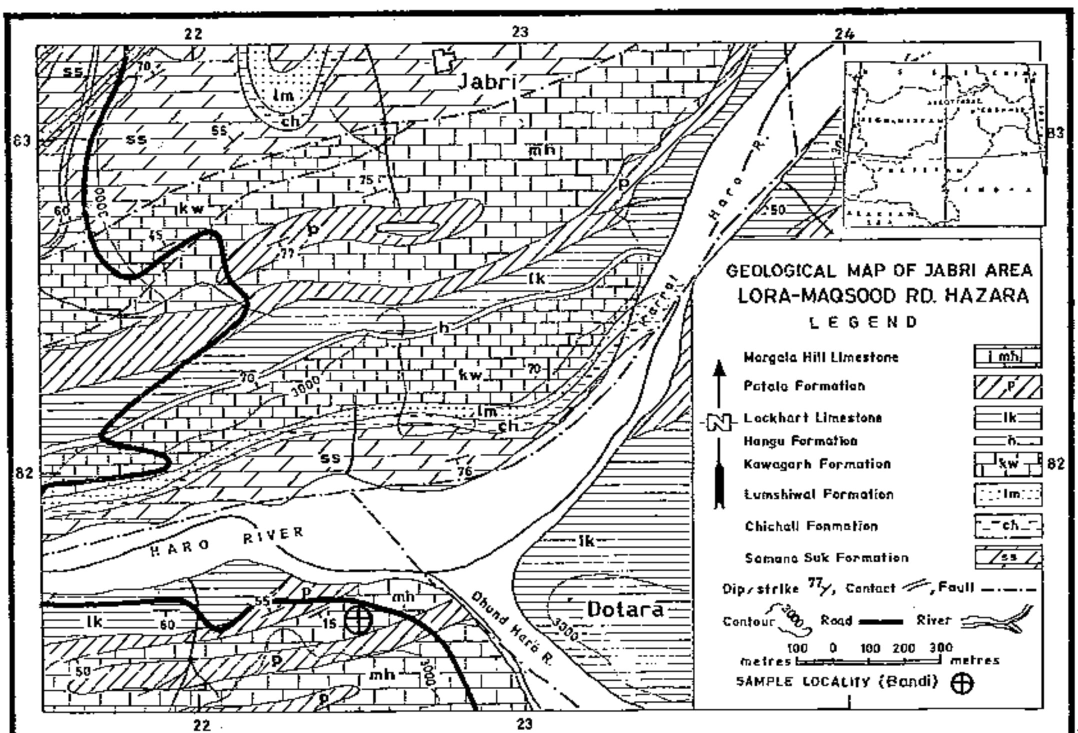

Fig. 1: Geological Map of Jabri Area Lora-Maqsood RD, Hazara.

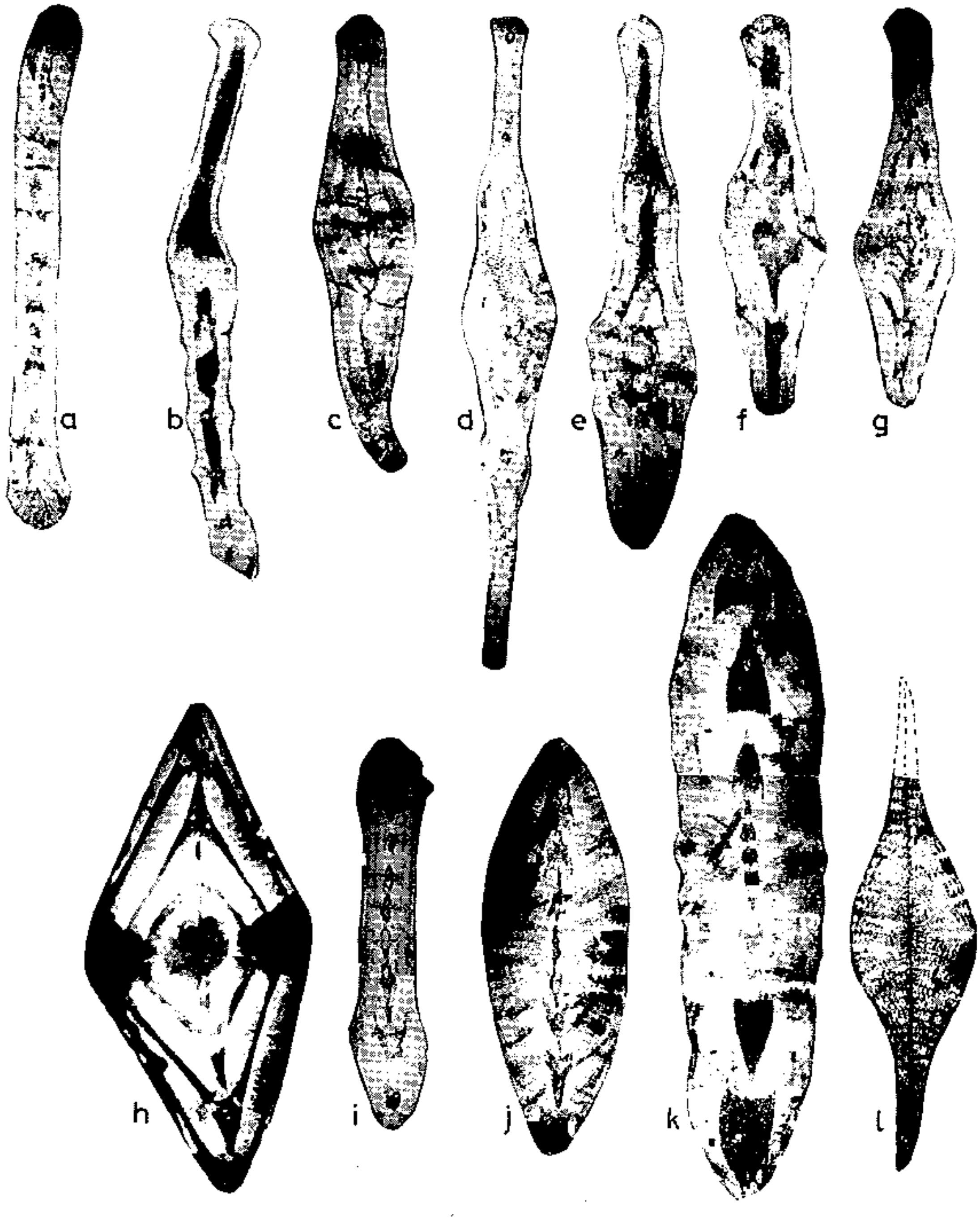

Plate I : a-b. *Ranikothalia sindensis* (DAVIES), c. *Ranikothalia nuttalli* (DAVIES), d-g. *Ranikothalia sahnii* (DAVIES), h. *Nummulites mamillatus* (FICHTEL & MOLL) i. *Assilina spinosa* (DAVIES & PINFOLD), j. *Assilina laminosa* (GILL) k. *Assilina granulosa* (d'ARCHIAC), l. *Discocyclina dispansa* (SOWERBY)

Global Distribution of Jurassic Foraminifera: Some Palaeogeographical Implication

S. GUPTA
Dept. of Geology, University of Lucknow, Lucknow (U.P), India.

The similarity of benthic foraminiferal species occurring in the northern hemisphere with that of the southern hemisphere is striking. These are studied here with reference to Jurassic foraminifera of Kachchh.

Middle to Late Jurassic smaller benthic foraminiferal assemblage recorded from Kachchh, Gujarat, western India, largely indicate cosmopolitan distribution and show marked affinity with the coeval fauna described from various parts of the world. Analysing the global distribution of such foraminiferal assemblages, it has been found that although numerous families occur, only a single family *Nodosareacea* dominates over others in relative diversity and number. It is also interesting to note that they show close and specific level similarities. Certain index species of *Epistomina, Garantella* and *Reinholdella* are also recorded for a limited time span in the sequence, from the northern and southern hemispheres.

A number of hypothesis have been proposed to explain this phenomenon. The most common explanation seems to be the shallow shelf sea realm, through which the migration of foraminifera might have taken place and this shallow sea might have connected the northern and the southern hemisphere during middle to late Jurassic times. Another possibility could be the parallel growth or bipolar distribution of foraminifera by which two morphologically similar benthic foraminiferal species could occur in two far off hemispheres nearly at the same time.

Sediment-Ostracod Relationship in the Gulf of Mannar, Off Tuticorin, East Coast of India

S. M. HUSSAIN, V. RAGOTHAMAN
Dept. of Geology, University of Madras, A.C. College Campus, Madras, India.
and
V. MANIVANNA
Dept. of Geology, Government Arts College, Salem, Tamil Nadu, India.

An attempt has been made to evaluate the sediment-Ostracod relationship, in the Gulf of Mannar, off Tuticorin, southern east coast of India. A total of 48 sediment samples were collected from 12 sampling stations. Twelve bottom sediment samples were collected once in three months, for a period of one year, so as to represent the four seasons (Winter, Summer, Southwest Monsoon and Northeast Monsoon). Calcium carbonate content as well as organic matter content of each sample was correlated against the Ostracod population recovered in the respective sample. It has been found that an increase in the $CaCo_3$ percentage and a decrease in the organic matter content generally favour a higher population size. Also, an analysis of the sand-silt-clay percentages of each sample correlated against population size, reveals that siltysand is the more favourable substrate for the population abundance, in the study area.

Palynological Studies of the Triassic-Jurassic Rocks of the Salt Range, Pakistan

SARFRAZ AHMED
Institute of Geology, Punjab University, Lahore, Pakistan

The Nammal Gorge is the most well studied area of the Salt Range in the upper Indus basin of Pakistan. Tredian, Kingriali Formations of Triassic and Datta Formation of Lower Jurassic have been studied palynologically. 60 samples from sediments of this area have been analysed. Lithologically these are composed of siltstone, sandstone, shale and dolomitic limestone of varied colours. Palynological flora of marine and non-marine sediments of this region contain a diversity of trilete spores, pollen grains together with an acritarch component that is relatively inconspicuous qualitatively and quantitatively. Based on qualitative changes in the palynological assemblages of Triassic sediments, it is possible to distinguish two successive zones. Each zone derives its name from two distinctive species which appear at the base of zone and are from base upwards: the *Falcisporites stabilis* --- *Verrocosisporites narmianus* ranging from Ladinian to Carnian, the *Gleicheniidites umbonatus* --- *Foveosporites foveoreticulatus* zone of Carnian-Norian.

It is of interest to note that all of these taxa mentioned above have not been observed in the unconformably overlying continental facies of the Datta Formation (Lower Jurassic). On the other hand, this stratigraphic unit is characterized, apart from other components, by the incoming of a trilete miospore *Matonisporites phlebopteroides* together with a pollen grain species *Cerebropollenites mesozoicus*. These forms have frequently been recorded in the lower part of the Datta Formation. The absence of *Veryhacium* in this deposit is in harmony with respect to the continental environments.

Physiognomy of Plant Fossils from Siwalik Formation : An Aid in Determining Palaeoclimate

M. PRASAD
Birbal Sahni Institute of Palaeobotany, Lucknow, India

The Siwalik Formation consists of an enormously thick succession of sediments deposited all along the Himalayan foot hills in Pakistan, India, Nepal and Bhutan. It extends from Brahmputra valley on the east to the Potwar p lateau and Bannu plains on the west covering a distance of about 2400 km in length and 20-25 km in width. The Siwalik sediments are made up of sandstones, grits, conglomerates, pseudo-conglomerates, clays and silts containing within them a rich assemblage of plant fossils.

So far, about 300 fossil taxa based on fossil woods and leaves have been described from Siwalik sediments of India, Nepal and Bhutan in the Himalayan foot hills. The physiognomic characters of all the known fossils have been analysed and an attempt has been made to deduce the palaeoclimate of the region during Mio-Pliocene times. The leaf physiognomic characters that have been used as an aid in determining past climate are mainly drip tips, leaf margin, leaf size and venation density. In the fossil assemblage a large number of taxa possess conspicuous drip tips, a characteristics leaf feature of many plants in excessive wet conditions which serve to drain rain water quickly. The dominance of entire margin species (90%) indicating prevalence of tropical climate. The other features like leaf size, leaf texture, nature of petiole and venation density etc. collectively suggest tropical climate with heavy rainfall during Siwalik period all along the foot hills.

Anatomical features of about sixty dicotyledonous woods that are believed to be of ecologic/climatic significance like distinct growth rings, narrow and wide vessel diameter, high and low vessel frequency scalriform perforations, vessel arrangement, ring porasity, height and width of the rays etc. have been taken into consideration. The occurrence of a high percentage of woods with indistinct growth rings indicated a tropical, non-seasonal climate. Further in the fossil assemblage there are mostly large vessels (over 200 um in diameter) accompanied by vessels of distinctly smaller size, low vessel frequency, simple perforation, almost solitary vessels with short radial multiples indicating a warm humid climate all along the Himalayan foot hills during Mio-Pliocene times.

Geology of Barhatta Thana, Netrokona District, Bangladesh

S. U. HUSSAIN
Geological Survey of Bangladesh, Dhaka

A geological map of Barhatta Thana, Netrokona District, Bangladesh was prepared at a scale of 1:50,000 (Topo Sheet No. 78 L/13). The map includes small parts of three physiographic units which are the Sylhet basin, the northern Piedmont plain and the old Brahmaputra flood plain. The following map units are included in the map: (a) channel sands; (b) active point bar deposits; (c) old point bar deposits; (d) old bar deposits;(e) nature levee deposits; (f) flood basin deposits; (g) fan deposits; (h) abandoned channel deposits; (i) ox-bow lake deposits; (j) backswamp deposits and (k) cover sands.

The study has contributed three derivative maps which are (i) the land use map, (ii) the economic deposit map, and (iii) the geological hazard map (showing bank erosion and ponds formed by flood water). A section map is also included.

The laboratory works have helped add a ternary diagram and a diagram of CM-patterns. The former has presented the textural nomenclature of sediments of the backswamps, the flood basins and the fan and the latter revealed the bottom turbulence and their hydraulic condition. These sediments are poorly to very poorly sorted. Their sorting may ascribe to a strong laden sediment current prevalent during the generation of the geomorphic units mentioned above.

Late Quaternary Fluvial History of Jammu Sub-Himalaya

R. K. GANJOO
PG Department of Geology, University of Jammu, Jammu, India

The recent dating of sea cores and its correlation with terrestrial deposits (Shackelton and Opdyke 1973) has revolutionized the earlier concept of four-fold glacial sequence to classify the post-Middle Pleistocene events of Sub-Himalaya. De Terra and Paterson (1939), biased with this concept of Alps, applied the four fold glacial sequence to stratigraphically arrange the late Quaternary deposits of Sub-Himalaya, including the Jammu Sub-Himalaya. However, Porter (1970) was able to identify only three glacial phases in Kohistan and dated them all to Pleistocene period. Fort (1985) proposed the existence of small scale valley glaciers in the intermontane basins of Nepal during the late Pleistocene which received further support from the palaeobotanical evidences (Mittere and Sharma 1984). Recently the thermoluminescence dates of loess deposits of Soan Valley (Pakistan) has provided fresh insight to the late Quaternary deposits of Sub-Himalaya (Rendell and Dennell 1986, Rendell 1988).

In view of the recent studies in Sub-Himalayan terrain adjoining the Jammu Sub-Himalaya, a critical field examination of late Quaternary deposits was carried out. The partially weathered secondary Boulder Conglomerate deposits, erosion benches and valley- fill deposits in Katra and Udhampur dun are the post-Middle Pleistocene events identified in and around Jammu. The studies have provided substantial field evidences to arrange these events in stratigraphical order and tentatively interpret the late Quaternary climatic and tectonic history of the area.

Sequence Stratigraphy of Quaternary Sediments in Saryu Basin, Central Kumaun Himalaya

L. NAIR and K. C. TIWARI
Department of Geology, M. S. University of Baroda, Vadodara, India.

The snow fed Saryu River constitutes the largest tributary drainage system of Kali river, bordering India and Nepal. The Saryu river and its sister streams, viz. Ramganga and Gomti display rich assemblage of Quaternary sediments of glacial, fluvial, limnic and residual nature. These river valley sediments are distributed as paired and unpaired terraces of three generations, viz. T_0, T_1, and T_2.

The overall sequence lithostratigraphy of the Saryu watershed has been divided into three formations viz. Lower Saryu, Middle Saryu and Upper Saryu formations, considering three major erosional surfaces. These formations based on sediment nature and dynamics have been further sub-divided into members viz. Thal, Urg, Kapkot (Lower Saryu Fm.); Rameshwar, Rithabgarh, Bageshwar (Middle Saryu Fm.) and Nachni (upper Saryu Fm.)

The deposition of these Quaternary sediments is attributed to minor perturbation in climatic regime which has been accounted to 02 stadials and 05 interstadial stages; ranging from Middle Pleistocene to Recent Time.

Studies on the Quaternary Sediments and Neotectonism in Kali River Valley, Kumaun Himalaya

K. C. TIWARI, L. NAIR and N. M. VASHI
Department of Geology, M.S. University of Baroda, Vadodara, India.

The Kali river bordering India and Nepal constitute the largest watershed in Kumaun Himalaya. Originating from the southern flanks of Zansker range (6500 m amsl), the Kali river display thick accumulation of Quaternary sediments. These Quaternary sediments are distributed at three different levels as paired and unpaired terraces characterised by fluvial, glacial, lacustrine and colluvial nature. The sediments are predominantly represented by thick bouldery horizons with occasionally thin sandy layers, thereby reflecting their deposition under flash floods, during the past aggradational phases of the rivers.

The inventory of neotectonic features with the help of IRS-Liss-I) imagery and field checks has revealed ample evidences of neotectonic activity predominantly in the vicinity of major intra-crustal thrusts and NW-SE, NE-SW conjugate transverse faults. The upper reaches viz. Bajhang-Dharchula area records seismicity of highest magnitude across the entire mountain range, which is attributed to the movements along these tectonic linears.

Upper Pleistocene Monsoon Climatic Fluctuations and the Depositional History of the Bengal

M. H. MONSUR
Department of Geology, University of Dhaka, Dhaka, Bangladesh

The peak of the last glaciation (18 kyr BP) was evidenced by dry climatic condition over the Bengal basin. The Himalayas were considerably high and were glaciated. Melt water was flowing through a number of palaeo-river system over the Bengal basin. By that time the eustatic sea level was about 100 to 130 m below the present Mean Sea Level. Hence, the rivers were narrow and were deeply incised (Swatch of No Ground in the Bay of Bengal is a strong evidence).

The monsoonic climate started changing between 18 to 15 kyr BP. At about 12 kyr BP, southwest monsoon became prominent which caused heavy rainfall. Therefore, at the end of the last glaciation (about 10,000 yrs BP) amplified monsoon water plus deglaciated melt water from the Himalayas enormously flowed through these narrow palaeo-river systems which were overloaded and overflowed. The initial surfaces of the Madhupur and Barind Formations (Lower to Middle Pleistocene) were eroded, leaving a north-south elongated landmasses. At the beginning of the Holocene, sea level started rising very rapidly. Abut 6500 yrs BP, sea-level attained its maximum height. The line drawn from Ganakghata to North Nalbila in the Maiskhali Island and also from Cox's Bazar to Teknaf (eastern extremities of salt marshes, about 1.5 m from the HT level) represent such an elevated palaeo-shore line. The hydrodynamic condition of the river system was changed. Erosional activities ended and the erosional surfaces were filled up by the Holocene deposits. Due to the tremendous current, boulders and gravels from Himalayas were carried away very far towards the east and were deposited over the vast plain extended from Tetulia to Dahagram (Panchagrh Gravel Beds). These upper Pleistocene gravels can be found in the Brahmaputra river valley as far as Sirajgonj.

In the Barind and Madhupur tracts, middle and lower members of the Barind and Madhupur Formations are overlain by Holocene deposits (Basabo and Chalanbil Formations). The Holocene infilling was not as high as the initial Madhupur surfaces. That is why, the Barind and Madhupur tracts apparently seem to be elevated compared to the surrounding flood plain. This apparent elevation of the flat surfaces of the Madhupur and Barind is an erosional feature and does not indicate a tectonic event.

Most of the hill tops of the Jointiapur area are capped by Lower Pleistocene gravel beds (Sona Tila Gravel Beds). These gravels seem to be equivalent to the Madhupur Formation. Hence, it is thought that the Jointiapur hills and the Lalmai hills were uplifted synchronously. This block upliftment of the Lalmai and Jointiapur hill and the hillocks of the Madhupur type locality took place probably during the Middle Pleistocene Epoch.

Classification of Aquifer in Dhamrah Kas Basin, (Wah Cantt.) Near Isalamabad, Pakistan

M.H. MALIK
Institute of Geology, Punjab University
Lahore, Pakistan
and
M. S. KHAN
Wapda Consultants, LBOD, Mir Pur Khas Project,
Sindh, Pakistan

Inter-disciplinary investigational techniques including hydrological reconnaissance, geo-electrical survey, test hole drilling, installation of tube wells and capacity tests were used for establishing hydrogeology in the Dhamrah Kas Basin, Wah cantt. area, Pakistan. A multi-layered semi-confined aquifer system (four in number) stretching in 150 sq km area has been proved with the help of 40 geo-electrical soundings, 20 test holes and 10 dug wells spread throughout the basin ranging in depth from 100-200 meters. The maximum and minimum thickness of the aquifer have been determined.

The aquifer has been classified as semi-confined fresh water body with an average well capacity of 250-350 gallons per minute. The topmost layer of aquifer is in severe danger of contamination near the northern boundary of the basin. The sewage disposal from the private settlements and industrial waste through the Dhamrah Kas nullah is recharging the aquifer system resulting coliform bacterial contamination and increase in total dissolved contents of groundwater.

Ground Water Recharge and its Management in the Terai Plain of Nepal - Bhairahawa - Lumbini Area as a Case Study

G. K. RAO
Department of Geology, Andhra University, Visakhapatnam, India
and
R. SHRESTHA
Groundwater Resources Development Project, HMG/N, Kathmandu, Nepal

Terai plain of Nepal is underlain by a thick pile of alluvial sediments. The three river systems of Himalaya, namely those originating from the Higher Himalaya, Mahabharat Range and the Churia hills, carry distinct nature of sediments. Shifting of river courses adds to the complexity of sediment distribution in the Terai plain.

Hydrogeological system of the Terai plain comprises unconfined aquifers close to the foothills of Churia Range and in the Bhabhar Zone and multi-aquifer system in the rest of the plain. However, the aquifer zones are of highly localized nature with possible vertical interconnection. Potentiality of the aquifers is highly variable with transmissivity ranging from 50 to 21,000 m^2/day.

It is generally considered that groundwater recharge to the confined aquifer system in the Terai plain is taking place only through Bhabar Zone. But some studies on fluid potential distribution in some parts of Terai plain including Bhairahawa-Lumbini area show that some other parts in the plain also acts as recharge areas. Paleo-channels are the other sources of recharge from the surface streamflows. It is therefore not logical to base the recharge estimates only on the rainfall factor, that too, confining to Bhabar Zone.

With an increase in withdrawal of groundwater in the Bhairahawa- Lumbini project area, between 1983 and 1988, there is a corresponding increase in the groundwater recharge, obviously, due to inducted recharge from the stream courses. The fluid potential of the deeper aquifers is much higher than that of shallow aquifers with flowing conditions and thus leakage is in the upward direction. It is suggested that the Terai plain be subjected to some degree of heavy exploration initially to assess the deferred perennial yield and finally to arrive at the appropriate safe yield factor.

Hydrogeological Conditions in a Dun Valley of Himalaya - Dang Valley, Western Nepal, A Case Study

G. K. RAO
Department of Geology, Andhra University, Visakhapatnam, India
and
B. PIYA
Kathmandu, Nepal

Dang Valley is one of the largest intermontane valleys in the Himalaya of Nepal. It is elongated with about 80 km in length and a maximum width of 30 km. The valley is deeply indented by a number of parallel system of streams flowing from north to south. They join the Babai river running along the southern margin of the valley from east to west.

The Dang Valley is surrounded by the Mahabharat Lekh on the north and by the Churia (Siwalik) hills on the other three sides. The valley is filled with fluvio-lacustrine sediments. Gravel, sand, silt and clay and their admixtures occur throughout. Fan deposits at the emerging points of the streams from the Mahabharat Range constitute mainly boulders, cobbles, pebbles and gravel. In the valley part, gravel and sand are the dominant sediments towards north while clays and silt dominate towards south. Lithologs of the tubewells reveal that sediment distribution is highly variable both laterally and vertically due to the influence of different streams.

Groundwater investigation has been initiated in the valley through 17 deep tubewells and 8 shallow tubewells by the GWRDB, HMG/N under UN/DTCD scheme during 1986-88. The granular beds develop water table, semiconfined and confined conditions in different places. Depth to water table varies from 0.15 to 10.3 m bgl as recorded in the month of October. Its seasonal fluctuation is 4.0 to 20.0 m bgl. Granular beds tapped by the tubewells show confining nature from a depth of 2.1 m. Exceptionally, Tarigaon-Lalpur area shows deep water table condition with the water table at a depth of 15.2 to 37.5 m bgl. In other areas, piezometric surface of both shallow and deep aquifers is at a depth range of 1.1 to 30.0 m bgl. When drawn with reference to mean sea level, the piezometric surface follows topography. Piezometric head is 4.0 to 58.3 m. Seasonal fluctuation of piezometric surface is 1.5 to 18.4 m. Maximum level is reached during July in the dug wells and August in the tube wells and starts declining from the end of September. These parameters have high values in the northern part and low values in the southern part.

Yields of the tubewells vary from 4.5 to 83 m^3/hr. Their Specific Capacity values are 0.22 to 15.9 lps/m of d.d. Transmissivity is 25 to 5670 m^2/day and hydraulic conductivity is 0.7 to 418 m/day.

A graph plot of piezometric head versus depth of the aquifer for the entire basin shows poor correlation. But it shows good symptomatic correlation when classified drainage basinwise. Piezometric head intensity per metre depth of the aquifer varies from 0.11 to 0.92. Correlation of this parameter with depth also shows similar behaviour. This reveals that the Dang Valley consists of a number of groundwater sub-basins related to each drainage basin.

Subsurface damming to arrest the outflow of groundwater from the valley is suggested at the outlet of Babai river and also at the confluence points of its tributaries.

Hydrogeophysical Studies for Groundwater Exploration in an Eastern Region of Islamabad, Pakistan

K. A. KHAN
Oil & Gas Development Corporation, Islamabad, Pakistan.

Hydrogeophysical studies were carried out in an area lying east of Islamabad. The main objectives of the study were to identify various groundwater potential aquifers and to establish a relationship between the geo-electric and hydrogeologic parameters. To acquire electrical parameters, an electrical resistivity survey comprising of 29 stations was carried out in the study area. At all the stations Schlumberger electrode configuration, with a maximum spread of 400 meters, was employed. The acquired VES curves were processed on a PC based software. The resulting true resistivity and thickness of various subsurface horizons were interpreted in terms of geological columns and cross-sections which revealed the presence of clay, sand, gravels and boulders as subsurface lithologies. The widely spread gravels and boulders, as water bearing strata, suggest that most of the regions of the project area are promising zones of groundwater aquifer. Both confined and unconfined aquifers have been encountered. The confined aquifer is bounded between impermeable layers of clay and sand.

The resistivity information was also used to calculate transverse and longitudinal resistivities which is turn were used to plot Dar-Zarrouk curves across selected profiles to determine the electrical behaviour of the aquifers. These curves show that the surficial layer is composed of high resistive material while the second layer constitutes the aquifer having high longitudinal conductance.

Finally statistical analyses comprising of linear regression were carried out to find out the relationship between electric and hydraulic properties of the aquifers. These analyses conclude that there is no significant relationship between electric and hydraulic parameters.

All the results were compiled to demarcate promising groundwater drill sites.

Major Ion and Isotope Geochemistry of the Dupi Tila Aquifer of the Barind Tract, NW Bangladesh

K. M. AHMED, D. MATTEY
Stable Isotope Laboratory, Dept. of Geology, Royal Holloway and Bedford New College, Egham, Surrey, U.K.
and
W. G. BURGESS
Department of Geological Science, University College London, London, U.K.

Barind is the land where life is written in water - the adopted slogan emphasizes the need for water in the region. The Barind Tract in NW Bangladesh is characteristically dry and the limited surface water of the area is affected by the Farakka barrage. The area has long been considered as a low potential area for ground water development. Since 1985, a large groundwater development project have been implemented in the area and about 5000 irrigation wells have so far been installed in about 5000 km^2 area. Pliocene Dupi Tila sands serve as the main aquifer in the tract and Recent alluvial sediments serve as aquifer along periphery in the east and west. The Dupi Tila aquifer is covered by a 30 m thick Pleistocene clay deposit and is not exposed anywhere. There are uncertainties in the amount and mechanism of recharge to the aquifer. The sustainability of this large scale abstraction has been questioned by environmental scientists. Hydrogeochemistry and isotope geochemistry (stable isotopes and ^{14}C age dating) of water samples from the area has been studied extensively for better understanding of the recharge mechanism and interaction between the surface water and groundwater of the area.

Chemical data suggest active recharge to the aquifer through the clay. Water is mostly $CaHCO_3$ type with only a few NaCl-type.

Chemistry also disputes the accepted hypothesis of river recharge to the aquifer. An evolutionary trend has been observed down a flow line along a major river of the area. However, a dilution effect superimposed on the regional trend near a large surface water body indicates the local role played by them in the regional recharge. Isotopic data show distinct grouping among different sources of water. No isotopically heavier surface water is specifically found in the aquifer. Isotopic data indicate a change in the temperature history of the area over the last 3000 years.

Significance of Isochemical Map for the Interpretation of Quality Data of Natural Waters Around Tighara Dam Site, District Gwalior (M.P.), India

D. C. GUPTA and A. GUPTA
Department of Applied Geology
Barkatullah University, Bhopal, India.

The geochemical nature of the surface and sub-surface waters of the area have been worked out for pre- and post-monsoon seasons. Geologically, the area comprises of Kaimur Sandstone, Rewa Sandstone and Recent Alluvium. The chemical analysis of 48 water samples located in Kaimur Sandstone and Recent Alluvium have been carried out for both surface and sub-surface water. The study suggests that the concentration of various cations and anions varies between very wide limit. The distribution pattern map for Ec., Total Hardness, T.D.S., Ca, Na+K and Cl have been prepared for pre- and post-monsoon water samples to work out schematic variations in the geochemical behaviour of various cations and anions of the natural waters in the area of study. In the present paper, an attempt has also been made to find out possible causes of variation in the isochemical contours of different constituents.

Groundwater Contamination Studies in Sonipet Industrial Area, Haryana, India

P. C. CHATURVEDI
Geology Department, Kurukshetra University
Kurukshetra, India.

The Groundwater contamination generally defined as changes in physico-chemical and microbiological characteristics or even in the content of radio-nuclides of water is a result of anthropogenic activities which makes it more health hazardous. The contaminating sources are usually defined as point source, non-point or diffuse source and line source. In this paper the possible line source contamination as prime component is studied. In the study area as a normal practice the untreated waste from many of industries are discharged in open fields and drains located nearby their premises, ultimately leading to the contamination of groundwater through infiltration.

The representative groundwater and soil samples were selected and analysed in terms of Total Dissolved Solids, E.C., pH, major and minor elements. The emphasis are given on conservative non-gradable substances, which do not change in concentration with time. An attempt has been made to establish the relation between Total Dissolved Solids and Electrical Conductivity to know the salinity status in the area. The general groundwater conditions are considered to determine the possible extent of ground water contamination.

Groundwater Contamination Study of the Sihala Industrial Triangle, Islamabad

K. A. KHAN, R. J. CHAUHAN
Oil & Gas Development Corporation, Islamabad
and
H. AKRAM
Quaid-i-Azam University, Islamabad

Physico-chemical, hydrochemical and biochemical studies of shallow groundwater aquifer of Sihala Industrial Triangle (Islamabad), lying south of Soan River, were carried out. The main objectives of the project were to study the type of aquifer system and to determine the area having highest concentration of plume. Water samples from 32 boreholes were taken from different places of the study area and analyzed in the laboratory for biochemical, physico-chemical and hydrochemical concentrations. Overall these tests comprise of coliform, faecal coliform, temperature, pH-value, Sodium Absorption Ratio (SAR), Total Dissolved Salts (TDS), Eelectrical Conductivity (EC), hardness as $CaCo_3$ and the determination of anions and cations. The chemically analyzed data was statistically treated to check the relationship and to correlate goodness of fit and correlation coefficient by applying bivariate statistics and linear regression of first, second and third order. Contour maps were drawn to determine the area of high plume by using the data based upon total dissolved salts and -ve, +ve coliform. Chemically analyzed data was projected graphically using stiff pattern and tri-linear piper diagram with a USGS software. Equipotential map was constructed using hydraulic heads.

A flow net map was also constructed through the flow tubes which exhibited the recharge and discharge areas, direction of ground water flow, number of flow tubes, and influent and effluent status of the Soan river. In conjunction with hydrogeological work geo-electric resistivity measurements using Schlumberger configuration were also carried out at seven stations in the project area. These measurements were used to establish the hydraulic characteristics of the aquifers, thickness and type of subsurface lithologies. The geologic interpretation revealed the presence of clay, sand, gravels and boulders as major subsurface units. The final results indicate that the groundwater of this area is not reliable biochemically and hydrochemically, but physico-chemically the water is suitable for industrial and domestic purposes.

Impacts of Geological Hazards in Pokhara Valley

A. KOIRALA and L. N. RIMAL
Department of Mines and Geology
Kathmandu, Nepal.

Pokhara valley is a Northwest-Southeast elongated valley extended from Bharabhari in Northwest to Bhimad in the Southeast. Total length of the valley is about 50 km and average width is about 5 km. Engineering and environmental geological mapping of the valley was carried out in two phases in the central and northern parts of Pokhara in 1994 and 1995.

The valley consists mainly of coarse grained sediments weakly to strongly cemented by calcareous cement. These sediments are the result of at least 3 major episodes of debris flow event along the Seti river from Annapurna region. They are named as Tallakot, Ghachok and Pokhara debris flow episode (Yamanaka 1982, Fort 1987). Surprisingly the material of the Tallakot debris flow episode was found about 3 km upstream of Mardi Khola (a major tributary of Seti river) diverting 90^o from its main flow course, which demands a stream and a lacustrine environment was created behind.

The debris flow episode had dammed the tributary valleys during the corresponding period contributing to the development of lacustrine environment, of which several examples can be cited. Although the age of the different debris flow episodes in Pokhara valley has yet to be determined, the age dated

for the latest event i.e. for Pokhara debris flow event (600-1100 yrs. B.P.) (Yamanaka 1982, Fort 1987) is debatable because of lack of any historical proof for this event.

One thing which is common for all the three debris flow events is that the material involved in all of them is dominated by calcareous sediment both in clasts and in matrix. Obviously the calc-rudites thus deposited are suffering from karstification of different intensity producing solution channels, chimneys and pinnacles giving rise to underground caves and cavities. Although the material deposited by Tallakot debris flow event is also suffering from the karstification as evidenced by the presence of mega-pinnacles, the material deposited by the Ghachok debris flow event has been found to be most susceptible for karstification.

In this context Pokhara valley is susceptible for such geological hazards as (i) Debris flow hazard, (ii) Karst hazard and (iii) Landslide hazard.

In this paper engineering geological description of the debris flow material of different episodes and their depositional extent is described. Intensity of sinkhole development and subsidence is discussed together with delineation of the area susceptible for subsidence hazard. Bank collapses along Seti river and its tributaries is highlighted discussing their implication to the human population and existing infrastructures.

Integrated River Basins Management - To Solve the Flood Problem of Bangladesh

R. M. EKRAM ALI
Geological Survey of Bangladesh, Dhaka, Bangladesh

Bangladesh lies in the southern extremity of the Ganges-Brahmaputra-Meghna river basins. This combined basin areas cover about 600,000 sq.miles, of which only 7.5% falls in Bangladesh. Major portion of these basins fall under India, Nepal, Tibet and Bhutan. Geomorphologically, Bangladesh occupies the lowest level of these basins and lies at the receiving end of this big hydro-dynamic system. Activities, specially from outside the country, both natural and man-made are creating different types of hazards in Bangladesh.

Flood is the most common hazard in Bangladesh, mainly resulting from the precipitation over the total basin areas. The average rainfall in Bangladesh can only generate about 100 million acre feet of water, whereas 1100 million acre feet of water comes from outside the country. The magnitude of flood depends on the magnitude of excess water coming from outside. Sometimes flooding becomes worse due to willful water flow diversion in the upper catchment areas. Hence, Bangladesh alone is unable to solve this problem as 90% of the basin areas is outside the country.

Integrated land and water management for the entire basin can only solve this problem permanently and effectively. Infrastructures development for storage and diversion of excess water is essential for this purposes. Soil erosion can be reduced by adopting proper land use policies, stopping deforestation and encouraging afforestation in the entire basin areas. On the basis of availability and demands, water should be shared in the watershed areas. Finally effective flood monitoring, forecasting and warning system should be developed on a regional basis.

The Environmental Impacts of Coal Mining in Punjab, Pakistan

S. AHMAD and U. FAROOQ
Institute of Geology, Punjab University, Lahore, Pakistan

The known coal fields in Punjab are confined to the Indus basin, which is the remnant of the regression of Tethys sea. The major coal fields occur in early Tertiary rocks. Coal seams are mostly lenticular with a thickness of a metre to a few meters. The Salt Range-Makarwal coal deposits consists of coal fields of eastern, central and western Salt Range.

Detailed mineralogical and chemical studies of the coal deposits indicate the downstream environmental pollution due to the associated sulphides (Pyrite), Gypsum, Clays, Halite and Carbonates. The presence of these minerals in and around the coal deposits of the area under study are affecting the downstream soil and water. During rainy seasons, the addition of toxic elements and fine sediments from the mining wastes increase the rate of downward pollution.

Some remedial measures are suggested to minimize the environmental impacts of coal mining in the studied area.

Environmental Geology and Disposal of Liquid and Solid Waste of Dera Ghazi Khan Area, Punjab, Pakistan

S. M. IQBAL, S. Q. RAZA, M. K. AKHTAR and M. HASAN
Geological Survey of Pakistan 16-G Model Town Lahore, Pakistan

Dera Ghazi Khan is a planned city located at foot hills of Suliaman Range and Lower Indus plains, Punjab. The increasing demands of natural resources have caused adverse effect on environments due to rise in population and more shifting to private agencies towards city area. To keep the normal conditions and setting of environments needs planning for future development of urban area. Environmental concerns include the process of urban development, availability of construction material, quality of groundwater, geological hazards and proper disposal of liquid and solid waste. Various problems of waste disposal of the area have been studied. Its effects on groundwater and agriculture land have been studied.

Environmental geology of Dera Ghazi Khan area has been summarized in a set of five maps on 1:250,000 scale in order to protect environments in natural setting and provide data to other agencies. The maps inform about i) geology of surficial deposits, ii) geologic and topographic data combined to form a map of landform, iii) resources of construction material, iv) geological hazards and land use planning map, that is all limitation on future use and iv) an indication of different environmental geological units for development of urban areas. These information can be organized to help urban planners, financial planners and government advisers for fast development of the area.

Degradation of Physical Environment in North Western Bangladesh

M. RAKIB UDDIN
Dept. of Geology & Mining
Rajashahi University, Rajshahi, Bangladesh.

The present work incorporates some physical determinants recorded in the northwestern part of Bangladesh. Field investigation reveals the depletion of groundwater level in many areas. This depletion may be related with the less precipitation, siltation problems in the catchment region and shallowness of river beds in channel networks. Excessive mega-sand bars in flow paths also causes over flooding and damages flood plain areas during rainy season thus threatening the whole eco-system. Proper management of sanitation in the source region of channel networks, afforestation program in barren areas may regulate to some extent the physical environment in near future.

Nature and Extent of Flood Hazard in North Bihar, India

S.C. GOSWAMI
Department of Applied Geology, Dibrugarh University,
Dibrugarh 786004, Assam, India

North Bihar plains, frequented by devastating floods, are drained by an extensive network of rivers all of which have a part of their catchment in the Nepal Himalaya. North Bihar rivers, while coming down from the Nepal Himalaya, bring enormous quantities of silt and constantly change their courses. The Koshi river has mnoved 120 km westward in the past 250 years through 12 distinct channels. Nothing better illustrates the vulnerability of North Bihar to floodhazard than the floods of 1987 during which 1.1 mha of cultivated area were completely damaged, surface communications got totally disrupted, nearly 30 million people were rendered homeless and 1100 people lost their lives.

In this paper nature and extent of flood hazard in North Bihar are discussed by taking into considerations factors that generally control flood damage - landuse on the floodplain, magnitude of flood, duration of flooding, sediment load deposited etc. -preventive measures and adjustments, and preception of the hazard.

Pleistocene Geological Mapping for Engineering and Environmental Geological Uses : A Pilot Study of Vishnumati Watershed, Kathmandu, Nepal

P.C. ADHIKARY and H. THAPA
Central Department of Geology, Tribhuvan University
Kathmandu, Nepal

Pleistocene geological mapping appears to be more feasible at a scale of 1:10,000 and the mapping methodology shows a natural watershed to be the most appropriate geographical unit for engineering and environmental conservation uses. Vishnumati watershed was chosen as a pilot area for methodological test. It was found feasible to discriminate ten litho-stratigraphical units of formation rank, of which Lukundol and Gokarna formations were already introduced. The following litho-stratigraphical formations are newly introduced; Champi fluvio-glacial, Chuni alluvial fan, Tudikhel fluvial, Budhanilkantha debris fan for depositional and Kotol-Taukhel debris flows (four in number) for erosional land forms.

Gokarna formation is a lacustrine deltaic foreset and is covered by younger Chuni and

Budhanilkantha fans and alluvial deposits in the north and deltaic topset of Tudikhel formation in the south. Kotol-Toukhel debris are essentially represented by weathered mud flows with prominent rubification. Champi fluvio-glacial deposits with thin mud flow cover is essentially developed over uplifted benches of Lukundol formation and pre-Tertiary rock outcrops along Sitapaila fault activities during the Middle Pleistocene. Southern limit of distribution of Gokarna formation is controlled by Balaju - Pashupati fault, north of which the watershed has experienced an important uplift throughout the Upper Pleistocene.

The only way to reconstruct paleo-environment and neotectonic chronology is found to be quite feasible at a scale of 1:10000 or a more detailed scale. It is expected to apply the used methodology for the mapping of other watersheds for environmental and engineering geological uses in the mountainous regions.

Slope Stability Analysis of the Heterogeneous Coastal Cliff by the Finite Element Method (FEM)

M. H. RAHMAN
Department of Geology & Mining
Rajshahi University, Rajshahi, Bangladesh

In this paper an attempt has been made to illustrate the problem of landslide and slope stability of heterogeneous coastal cliff of Cox's Bazar area, Bangladesh.

The calculation of the safety factor of the slope of the coastal cliff were done by finite element method (FEM) and by the widely used traditional methods. The values of the safety factor indicates that the slope is stable but the coastal cliff slope has a history of failures in different places every year.

Undisturbed monolithic soil samples were collected for different laboratory tests. The soil parameters which were used for the slope stability calculations were obtained by Unconfined compression, Triaxial compression and Direct Shear Box tests performed in the laboratory.

The results of the study include the distribution of vertical stress, horizontal stress, shear stress, maximum shear stress, principal stresses, displacements and the safety factor (SF) of the coastal cliff slope.

The satisfying results of the slope stability analysis of the coastal cliff lies mainly in a proper engineering-geological recognition of the slope and evaluation of the physico-mechanical parameters of soil including their natural changeability.

Geographic Information System for River Pollution Monitoring: An Environmental Approach in Parts of Yamuna, India

S. PAUL
World Wide Fund for Nature, New Delhi, India
and
S. K. SWAIN
Department of Geology, Delhi University, Delhi, India

Rapid industrial growth in the cities along the river have no doubt brought economic prosperity but there is also spate in the industrial and domestic pollutants which create an environmental problem. Industrial waste and partly treated sewage are channelised to Yamuna through sixteen drains/nalas to dispose off the material. Najafgarh drain have the longest catchment and passes through the industrial belt of the Union Territory of Delhi which contribute more than seventy percent of the BOD. As requirement of water for industrial, irrigational and drinking purpose is increasing steadily over the years, more reservoirs and barrages are erected in the river which drastically reduced the flow hydraulics

thereby hindering dissemination of pollution load. A hydro-chemical, hydro-zoological and associated hydro-environmental indices showing their impact on water quality in the parts of Yamuna river have been undertaken. A map of the stretch of the river was created by linking the 'point source' database maintained in a GIS platform with the spatial dimension of the river morphology. On the basis of Central Pollution Control Board's (CPCB) standard twenty-two parameter analysis, eight different pollution indices marking their effect on Yamuna river water quality have been mapped along with violated indices between Palla and confluence of Chambal.

Remote sensing satellite data analysis for sediment load in the river helped in locating sites to make provision for increasing the flow conditions to dilute the waste material. Temporal analysis by comparing different time-periods remote sensing data enabled to visualise the changing pattern and emerging trends in river sinucity by declining flow regime and higher rate of deposition.

The environmental policy on 'best designated use' of river water requires to have a complete database to formulate future activities and control of pollution at source. The study illustrates the capability of GIS for pollution monitoring to make decisive river basin planning.

According to the norms for calculating Bacteriological, Nutrient, Organic, Industrial, Pesticide, Benthic, Saprobity, Biological Diversity and Production Respiration index, the non-spatial data was retrieved from the database and the river stretch was digitised along with the point-data to locate the 'Violated Indices' and then regrouped area wise according to their inter-relationships using the capability of a GIS.

Fresh Water Quality and Their Management in the Coastal Areas of the Gulf of Khambhat

M. B. ISLAM
Department of Geology and Mining, University of Rajshani
Rajshahi, Bangladesh

The coastal tract of the Gulf of Khambhat exhibits variable hydrogeological regimes which can be categorized in conjunction with the prevailing geomorphic and lithologic configuration and hydro-climatic variations. The occurrence of potable water, to a large extent is influenced by the geomorphology and the sediment characteristics.

A delicate balance exists between unconfined sweet water and the underlying saline water in the coastal areas, and the groundwater circulating in different lithologies have developed chemical characters conformable to the constituent minerals. Contamination of freshwater by sea water too has added significantly to the dissolved constituents which is ultimately reflected in the chemical quality of the groundwater.

The paper embodied fresh water resources and its quality of the onshore saline tract of the Gulf of Khambhat. Water samples were collected from representative locations around the Gulf and were analyzed for determining their Total Dissolved Solid (TDS), Hydrogen ion concentration (pH), Cations: Sodium (Na), Potassium (K), Calcium (Ca) and Magnesium (Mg); Anions: Carbonate (CO_3), Bicarbonate (HCO_3), Chloride (Cl) and Sulphate (SO_4).

It is found that the amount of Sodium, Potassium, Calcium and Magnesium are in the range of 30-6800 mg/l, 1-700 mg/l, 1-380 mg/l and 1-1150 mg/l respectively. Whereas Carbonate, Bicarbonate, Chloride and Sulphate are in the order of 0-330 mg/l, 153-1980 mg/l, 70-5680 mg/l and 12-1484 mg/l, the TDS and pH values are between 256-15163 mg/l and 6.9-9.2 respectively.

The determined quantity of Sodium, Potassium, Calcium, Magnesium, Carbonate, Bicarbonate, Chloride and Sulphate exceeds the allowable limit as prescribed by the World Health Organization (Raghunath, 1987). The pH values are within the permissible limits but the TDS exceeds the value of USGS Classification (Heath, 1982). Excess Sodium and Chloride content of the drinking water gives the water a salty taste affecting the inhabitants with cardiac difficulties, hypertension and some other problems. The higher concentration of Calcium, Magnesium, Carbonate and Bicarbonate makes the water very hard. Higher concentration of Sulphates gives water a bitter teste.

It is suggested that besides the existing man-made storage of drinking water (as dugwells and ponds), shallow and big polyethylene layered ponds may be constructed at appropriate locations to receive seasonal rainfall. Evaporation loss may be reduced with the help of chemical treatment. Also, coastal villages should be connected with pipelines and water tankers may be provided to improve the living condition of the coastal inhabitants in extreme climate.

Environmental Impact Assessment of the Quality of Surface and Sub-surface Waters of Mansar Manganese Mine Area District -Nagpur, India

D. C. GUPTA, A. GUPTA and G. S. DESHMUKH
Department of Applied Geology
Barkatullah University, Bhopal

The area of present investigation consists of an arcuate shaped Mansar hill, which is about 3 km long and 0.75 km wide in E-W and N-S direction respectively. The ore body in the Mansar area consist of Gondite, black quartzite, manganiferous quartzite and interbedded and co-folded ore bands in the central portion. The ore body is lenticular in nature and show bulging and thinning along its length. Therefore, the width varies from 5 feet to as much as 35 feet on the surface. The mining activity in the area is mainly confined along Mansar hill. In the initial stage the mining was started with open cast mining which later on diverted into underground mining method. The environmental impact assessment of Mansar Mn mine is worked out by collecting the water samples from surface water, mine water and groundwaters and their subsequent analyses. Hydrochemistry of natural waters indicates that surface waters have low concentration of major cations (Ca, Mg, Na, K), major anions (HCO_3, NO_3, Cl, SO_4, PO_4) and trace elements (Fe, Mn) than the groundwater and mine waters of the area. On the basis of major cations, anions and trace elements of natural waters, it is worked out that these waters are suitable for domestic purpose, according to the specification laid down by WHO (1971) and ICMR (1975).

The parameters like Kelley's ratio, RSC, SAR, SSP and U.S. Salinity class have been determined to know the suitability of natural waters for irrigational purposes. The calculated values of these parameters suggest that most of the values are within the permissible limit of agricultural suitability except that the surface water in US Salinity Laboratory Staff diagram have been classified in C1S1 class, while groundwaters and mine waters fall inn C2S1 class. The study suggests that development and mining activity of Mn in the Mansar area have got no pronounced environmental impact on the hydro-ecosystem of the area. In the present paper an attempt has been made to discuss the variation caused in the hydrochemistry of natural waters and environmental impact on Mn concentration on plants and biota in general.

Erosion and Sedimentation Processes in Nepal, Their Effects and River Bank Protection Works with Special Reference to Hill Development and Control Measures in Nepal

S. B. UPADHYAY
Multi Disciplinary Consultants (P) Ltd.
Kathmandu, Nepal.

Nepal is a country having variable topography, climate, rainfall at different sectors and due to steep landform, the rivers are more violent. The almost 6000 numbers of rivers, streams and rivulets stretching from the Himalayas on the north to the Gangetic Plain has the drainage density 0.3 km/sq km which shows the closeness of the spacing of the channels and contribute the estimated annual run off of the order of 200 cu km out of which 165 cu km from Nepal only. In Himalayan river erosion process is influenced by occurrence of glacier outburst floods which deposits sediment especially when the rivers flow through broad valley located between the high mountains and in Mahabharat ranges landslides and erosion of river bank generally result in huge sediment concentration.

All these rivers travel down from high mountain to Terai and finally meet the Ganga river in India. As these rivers travel down, they create various problems like aggradation and flooding. Because of the natural landslides and man made problems like deforestation, agriculture, grazing, construction of roads, canals etc. in weak geological zone, the magnitude of the loss of soil mass caused by the rivers and other means have been increased year after year. The nature and the magnitude of the problems vary according to the different stages of the rivers. To create an ecological balance within a drainage basin, the affected people must seek some means of training these rivers.

The rivers at the mountain stage are very steep and beds are formed of exposed rocks and boulders. The flow rate is quite fast and the flow channel is confined between banks. The catchments contributing to the flows, are mainly steep sloped, thin forest and unterraced agriculture land. Usually the bed rocks do not get disturbed but the sediment like boulders and gravel brought from Himalayan area often rises the river bed and are, liable to move during high flood period. Due to the fluctuation of the river bed, the needs for river training works will always be less.

At middle hill stage, mostly the rivers have less steep gradient and have a tendency to shift both laterally and vertically, the beds are covered with smaller boulders cobbles and gravel brought from the mountain stage. They are met with other tributaries and proceed below. On both banks of these major and medium rivers, well terraced, flat plain areas called tars exist which mostly have permanent irrigation schemes. For the area above the flat plains larger number of farmers built small canals exists which are abstracted from the tributaries of the main river. These little canal systems are damaged frequently by landslide and soil erosion which have to be repaired. These rivers have submersible banks which are over-topped during floods and damages the canal system.

The characteristics of rivers and classification are (i) Single channeled straight aligned (ii) Single channeled meandering rivers and (iii) Braided rivers. The first category have steep gradient, form rapids and have high velocity to move boulders, gravel and cobbles during high flood. The second ones have moderate flow velocity with moderate gradient. The third category stream is supplied with more bed material than it can transport.

The rivers in hilly area have side erosion and forms landslide in some area where as in other area flat land called tars are formed on its both banks. Bank erosion may be natural or man made factor or both. Bed rising problem are caused by the balance of incoming and out going of the sediment in about the center of the river bed and diverts the river flow at the banks of the river which also causes for side erosion.

Lowering of the river bed may be due to one or combination of rate of sediment inflow being less than the transportation capacity of the river.

For the successful design of river training works, related to hill irrigation schemes, the irrigation system is to be located in stable geological reach and protection major of gully erosion, landslides etc. are to be studied.

For river training works details of catchment area like, drainage pattern, gully formation, hill slopes, soil nature, occurrence of landslides in the drainage system, main river channel flow location, high flood level, deepest bed level etc. are also need to be incorporated.

To assess for solving river problems the character of the river and the nature of the problems are to be assessed to solve river problems such as holding the river in existing channel, relocate the main flow channel by using spurs, embankment, cutoff etc. For river control measures such as fixation of Waterway, flood height at different return period, estimation of Manning's rugosity co-efficient, scour depth, silt factor, spacing of the spurs etc. are also incorporated in the study.

To stabilize the existing hill irrigation, river bank erosion and existing landslides 10 different watersheds of Nepal out of which 5 water sheds from high mountain and 5 from Mahabharat range were studied. The above watersheds of Himalayan foot hill covers 2825 sq km and river length 235 km. Where as in the 5 watersheds of Mahabharat range covers 3000 sq km and river length 225 km. The existing hill irrigation works to be executed in these watersheds were found out, based on Indrawati watershed in Sindhu Palchok district executed by water Energy Commission secretariat. But the river training works to be executed in these watersheds were also based on flood control of Andhi Khola done by Multi Disciplinary Consultants.

For river bank protection and river training works about 4200 m length of spur with 6065m long embankment at Mahabharat range watersheds were found essential. But in Himalayan foot hill watersheds, glacial lake outburst carries enormous quantity of the sediment and rises the river bed vertically and laterally due to which no major river training works can be executed to control the problems. Any water resources structure are to be executed in these rivers, glacier lake out-burst in Himalayan area must be reduced, which will tremendously reduce huge sediment incoming in these river bed. From this study, roughly it reveals that about 332 million rupees for such work may stabilize the flood problems of these watersheds.

For co-ordination purpose, a master plan should be prepared for more problematic rivers. The following is recommended for more scientific approach of river training works.

1. Master plan should be based on hydraulic analysis and proper design criteria to fix up the design parameters such as: Design flood, Water way, flood levels, coefficient of rugosity, silt factor, scour depth, type of spurs, embankments, guide bunds, marginal bunds etc.

2. Further educate people through newspapers, radio, television, songs etc. about the importance of maintaining ecological balance by adopting soil conservation measures.

3. In the places where geological devastation is likely to occur, detailed geological study be done if any irrigation canal or road has to be constructed.

Role of Geology in Tunnelling and Tunnel Support (With reference to the Khimti Hydropower Project)

S. C. SUNUWAR
Engineering Geologist, Butwal Power Company, Khimti Project, Nepal
and
B. O'NEILL
Geotechnical Specialist, Butwal Power Company, Kathmandu, Nepal

Nature leaves many geological clues which are very useful in planning and constructing underground excavations. Geological clues help in:

*selecting favourable tunnel alignments and portal locations to minimize stability concerns.
*designing tunnel and cavern shape, and determining rock support requirements
*locating weak zones before they are encountered so that the appropriate precautions can be taken
*predicting rock burst and rock squeezing problems.

Thus it is necessary to understand the geology of an area prior to starting underground excavation.

There have been relatively few tunnels constructed in Nepal and most of those constructed have small diameters and did not require extensive support. Therefore, there is a shortage of local tunnelling experience to offer guidance in selecting efficient rock support systems. A systematic method of determining the appropriate tunnel support is required to avoid collapses and minimize costs as larger and longer tunnels are planned.

Construction of the Khimti Hydropower Project in central Nepal has recently started. There will be a total of 11.5 km of tunnel ranging in diameter from 3 m to 5 m. In addition there will be a 73 by 16 m power house. The project area lies in the Melung augen gneiss schuppe zone, and the quality of the rock is expected to vary significantly. In order to minimize the rock support costs, it is proposed to classify the rock in accordance with the Q-system and use guidelines for rock support developed in Norway by Barton et al.

This paper reviews: the Q-system and the information that is available from Barton's guidelines; the importance of accurate logging of tunnels; the logging system used at Khimti; and the proposed permanent rock support.

Difficulties encountered in applying the guidelines and questions about their applicability to local rock conditions are also discussed. The limitations of Barton's guidelines and the need to modify them to produce guidelines more applicable to the local rock conditions are presented.

The Distribution and Engineering Properties of Fine Grained Soils of Kathmandu Valley

T. P. KATEL
Central Department of Geology, Tribhuvan University, Kirtipur Campus, Kathmandu, Nepal

G. S. POKHAREL
Soil, Rock and Concrete Laboratory, Nepal Electricity Authority, Kathmandu, Nepal
and
B. N. UPRETI
Department of Geology, Tribhuvan University, Tri-Chandra Campus, Kathmandu, Nepal

This paper deals primarily with the distribution, engineering and geotechnical properties of fine grained soils in the Kathmandu Valley. No much studies on engineering and geotechnical properties of these soils have been made in the past except in some engineering construction sites like bridges and heavy buildings. Very few data are available on the subject (Koirala et al. 1993; Sadaula 1993; Shakya 1987; IOST 1986,1983,1985; Soil Test, 1990 etc.). The

present authors conducted a detailed laboratory studies on the soils of Thapathali and Ratnapark areas. An attempt is also made to evaluate the soil conditions of Kathmandu Valley based on the available data from previous studies made by various agnecies.

The soils of Kathmandu Valley are mainly produced by weathering of rocks within its watershed boundary and are in most part lacustrine and fluvial in origin. They are composed of clayey, silty, sandy and gravely sediments. The north and the north-eastern parts of the valley consist of thick, medium to coarse grained sandy layers and subordinate thin clayey layers, whereas the central and southern part have thick clays (with peat and lignite) and thin fine to medium grained sandy layers. The maximum thickness of the sediments is found in the central (550 m at Bhrikutimandap)) and southern part (>457 m at Harishidhi) of the valley.

The engineering properties, basically the index (such as natural moisture content, Atterberg limits, specific gravity etc.) and mechanical properties (such as penetration resistance, cohesion, compressibility as well as angle of shearing resistance) of fine grained soils of Kathmandu Valley considerably vary both in horizontal and vertical directions.

The grain size analysis of Thapathali soils have shown a clear dominance of fines (fraction smaller than 75 microns) and that the percentage of sand and gravel is generally very low. The soil of Ratnapark contains a higher percentage of coarse fraction compared to the Thapathali soils.

The natural moisture content of Thapathali soil is generally high (72-125.13%). The moisture content of the soils of Ratnapark area is found between 9.1 (in coarse grained soils) and 68.3.Various other studies have shown that the moisture content of cohesive soils of parts of Kathmandu Valley ranges between 19.96 to 94%.

The specific gravity of subsurface soils (up to a depth of 15 m) of Thapathali ranges from 2.44 to 2.70 and soils of Ratnapark ranges from 2.66 to 2.73. The specific gravity of the surface soil of Lukundol on the other hand, showed a minimum value (2.34) and that of Arubari the maximum (2.67).The values of specific gravity of cohesive subsurface soils of other parts of Kathmandu Valley ranges from 2.51 to 2.77.

The bulk density of cohesive soils of the Kathmandu Valley ranges from 1.09 to 2.77 gm/cm^3. But most of the values fall within the range of 1.5 to 2 gm/cm^3.

The soils of Thapathali have high liquid limit (81.10-108.0%), and the plasticity index ranges between 13.01 to 40.0%. The liquid limit and plasticity index of the Ratnapark soils, on the other hand, range from 36.0-73.0% and NP (Non-plastic) to 33.0% respectively. Generally, the cohesive soils of Kathmandu Valley fall within medium to stiff consistency range. The cohesive soils of Tripureswor area are characterized by soft consistency and that of Singhadurbar, Jawalakhel and Chobhar have high value of consistency.

The cohesion value of Thapathali soil ranges from 4.25 to 7.17 t/m^2. The unconfined compressive strength of soils of the same area ranges from 8.5 to 14.34 t/m^2. At the Ratnapark site, the soils up to 5 m depth are non-plastic and the cohesion value is very low (0 to 2.5 t/m^2), and the angle of shearing resistance ranges from 28^o to 360^o. The cohesive soils of the area between the depth of 5 and 10 m have 0.76 to 3.34 t/m^2 cohesion value. The unconfined compressive strength of Ratnapark soils (between 6 and 10 m) ranges between 1.5 and 6.68 t/m^2 which indicate soft to medium consistency. The previous works conducted by various agencies have shown that the values of cohesion in other parts of Kathmandu Valley range between 0.3 and 11.15 t/m^2 , and the frictional angle from 2 - 42^o (the higher values may be due to the higher proportion of granular material).

The compressibility value of Thapathali soils is found to be low to very low suggesting a lower value of total settlement of structure founded on these soils. Similarly the results of consolidation test of soils of Ratnapark show that clayey silt have low to very low compressibility. The result of consolidation test (i.e. m^v, Cv and Cc) of different soil groups obtained by previous studies at various locations and depth of the Kathmandu Valley show that the soils are characterized by low to very low compressibility values. It is also supported by the results of SPT and unconfined compression test.

The allowable bearing capacity of foundation soils of Thapathali and Ratnapark areas for an allowable settlement of 25 mm for different types of foundation have been calculated as under:

(a) For a strip foundation of width of 1 m and founded at 1 m and 2 m depths below the ground level : 4.2 and 4.3 t/m^2 (Thapathali) and 9.15 and 9.89 t/m^2 (Ratnapark).

(b) For an isolated foundation of square shape of 2x2 m size and founded at 1 and 2 m depth below the ground level: 5.3 and 5.52 t/m^2 (Thapathali) and 5.78 and 6.0 t/m^2 (Ratnapark).

The bearing capacity of foundation soils for an isolated foundation of square shape of 2x2 m size and founded at 2 m depth below the ground level at different locations of the Kathmandu Valley (other than Thapathali and Ratnapark) were calculated using data from previous studies and were found to range from 6.6 t/m^2 (Kalimati) to 20 t/m^2 (Jawalakhel). It is also found that the bearing capacity of cohesive soils of the Kathmandu Valley increases with increasing SPT values. In general the lacustrine soils of Kathmandu Valley are therefore weak having a low bearing capacity and is capable of supporting only normally loaded structures. For heavily loaded structures special foundation technique should be applied.

It is commonly found that most of the buildings in Kathmandu Valley are founded on isolated and strip types of foundations and the foundation depth is 1 to 3 m below the ground level. The study of soil properties of Kathmandu Valley indicate that the heavy loaded structures should be founded on either raft, mat or pile types of foundation.

References

Institute of Engineering, 1986. Final Report on Soil Investigation Program of Institute of Engineering Development Project Pulchock, Kathmandu, *(unpublished report).*

Institute of Engineering, 1985. Report on soil investigation of Karmachari Sanchayakosh at Kantipath, Kathmandu, *(Unpublished report).*

Koirala, A., Shrestha, O.M., & Karmacharya, R. 1993. Engineering Geology of the Southern Part of Kathmandu Valley. *Bull. Dept. Geol. T.U., Kathmandu, Nepal. Proc. Workshop, Geoscience : In Mountain Environment and infrastructural Development, Vol. 3, No. 1, PP 151-159.*

Sadaula, D.K., 1993. Sands in Kathmandu Valley, Prospects and Problems. *M.Sc. Dissertation submitted to the Central Dept. of Geology, Tribhuvan Univ., Kathmandu.*

Shakya, U., 1987. Engineering Geology of Kathmandu, Nepal. *M.Sc. Dissertation submitted to AIT. Bangkok, Thailand.*

Soil Test (P.) Ltd., 1990. Report on Soil Investigation of International Conventional Hal, New Baneswor, Kathmandu *(Unpublished Report).*

The Dranglung-Chu-Fan An Outstanding Example of a Hazardous Event in the Upper Langtang Valley, Central Nepal

H. J. IBETSBERGER
Institute of Geology and Paleontology, University Salzburg, Hellbrunnerstrabe 34, A-5020 Salzburg (Austria)

D. P.MADHIKARMI
Department of Mines and Geology Lainchaur, Kathmandu, Nepal

The Langthang valley is situated in central-north Nepal, about 60 km north of Kathmandu. The nearly E-W striking valley belongs to the high situated valleys of the inner Himalaya, flanked on both sides by the chains of the Himalaya. The west-facing valley is highly influenced by the monsoonal circulation (e.g. summer monsoon).

The Dranglung-Chu fan, at an altitude between 3850 m and 4050 m. is located in the upper Langthang valley, between Kyangjin Kharka and the airstrip. The giant extension of the fan is most interesting, because of its uniqueness in the whole valley. The reason for that is easy to explain. The entire catchment area of the Dranglung-Chu lies in the terrain of the landslide deposits of Tsergo-Ri. The appropriate valley slopes show highest morphological activity, with debris cones elongated to more than 500 m. Extremely high erosional rates can be assumed.

One of the intentions of our studies was to observe the development and the changes of the an-complex between 1970 and 1993. For these investigations color and black & white photographs were analyzed (Schneider, 1970: Heuberger, 1978; Schneider, 1983; Miehe, 1986; Ibetsberger, 1990-91-93), additional to the field investigations.

Schneider, 1970: The orographical right side of the fan shows an episodic activity, mainly after the melting of snow in spring and/or the summer monsoonal activity. The neighboring zone in eastern direction can be characterized as the actual river-accumulation-area with permanent activity all over the year. The orographical left side of the fan shows no signs of morphological activity (inactive), is vegetated with grassland and tilled with some alp-huts (seasonal settlement of Dzongdi).

Heuberger, 1978: The orographical right side of the fan shows less variability compared to 1970. Between 197 and 1978 the neighboring zone is eastern direction - with permanent activity - developed belly-like into the inactive, vegetated area, where the alp-huts of Dzongdi are situated. A catastrophic debris flow must have occurred during an outstanding monsoonal event, because some alp-huts (especially at the contact) were awfully damaged. The further inactive area of the fan shows no changes since 1970.

Schneider, 1983: The air-photography of Schneider corroborates the increase of the permanent active zone, which was first documented by Heuberger (1978). Also the destroyed alp-huts of Dzongdi were visible.

Ibetsberger, 1990 (fig. 1)91-93: The actual morphodynamics at the orographical right side o the fan can be characterized as episodic. The covering with vegetation is more advanced compared to 1970, 1978 & 1983. The neighboring zone is eastern direction, the actual river-accumulation area, shows permanent activity, intensified mainly during heavy monsoonal thunderstorms and the melting of snow. The rapid belly-like advance of the zone of permanent activity into the zone of inactivity (partial demolition of the alp-settlement Dzongdi) above mentioned is still visible, but the hazardous processes have stopped. Since this event the seam zone reaches an evident stabilizing input.

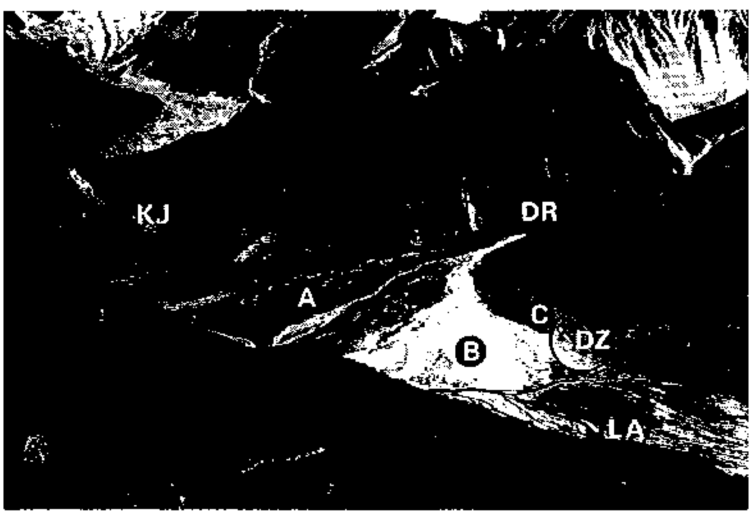

Fig. 1: The Dranglung-Chu fan seen from the south side of the Langthang valley (4360 m). A: Zone of episodic activity; B: Zone of permanent activity; C: inactive area of the fan; (LA: Langthang valley, DR: Dranglung valley, KJ: Kyangjin Kharka, DZ: Dzongdi); Photo by Ibetsberger: 15 11 1990.

Summarizing the most important facts of these investigations it has to be pointed out, that between 1970 and 1978 a catastrophic debris flow must have occurred. But since this hazardous event it is to observe that the whole fan-complex obtains a stabilizing input (decrease of the permanent active zone, resettlement with vegetation). But it is obvious that the whole fan-complex is conditionally unstable and can be endangered easily again during extraordinary monsoonal events.

Electrical Conductivity of Groundwater in a Landslide-Area with Uniform Lithology (Tsergo Ri Landslide, Langtang, Nepal) Spatial Trends and Application

J. T. WEIDINGER, J. -M. SCHRAMM

Institute of Geology and Paleonotology, Salzburg University, Salzburg, Austria

and

D. P. MADHIKARMI

Department of Mines and Geology, Kathmandu, Nepal

An outstanding example of single mass movement events (prehistoric) is to be found in the Langthang valley (central-north Nepal), about 60 km north of Kathmandu. The huge mass of coherently displaced rock and debris (about 109 m3), at Tsergo Ri as much as 450 meters deep, and frictional fusion (sliding surfaces) resulted from the failure of Yala Peak (5520 m) and Dragpoche (6562 m). Differences in altitude (1500-2500 m) between the main scarp and the recent floor of Langthang valley (altitude about 3950 m) illustrate the high relief. Heuberger et al. (1984) provided basic morphological and petrological data, Weidinger & Schramm (1994, 1995) reported from engineering geologic view.

The migmatites and intruded leucogranites, biotite-feldspar gneisses (augen gneisses), biotite-sillimanite gneisses and biotite-garnet gneisses surrounding the landslide-area are to be included in the High Himalayan Crystalline (Langthang Migmatite Zone: Kyangjin and Langshisa Unit, Reddy et at., 1992).

In general, unfractured crystalline rocks are aquicludes, have low porosity, whereas their permeability mainly depends upon structural properties (i.e. tortuosity of flow paths). First field work (engineering geologic map, joint density analyses) in the landslide-area attested rather uniform lighology, but significant graduation in disintegration of rock (Weidinger, 1992). Specific distribution of surface moisture and a series of springs pointed to alternations of aquicludes and aquifers within the landslide-deposit. However, difficult topographic and infrastructural circumstances restricted the applicability of geohydrologic methods (portable equipment). Thus, seasonal determination of selected parameters (electrical conductivity at 25°C, Temperature pH) of waters proved as simple but efficient tool. According to pathways in crystalline of < 300 mg/litre was to be expected (corresponding with an electrical conductivity of 210± 5% uS. cm_{-1}

Despite this expectation, geohydrologic parameters - analyzed at 81 representative springs - showed predominantly higher electrical conductivities (> 200 uS. cm^{-1}).Electrical conductivity correlates with the grade of rock loosening. The higher the disintegration of hard rock, the higher the electrical conductivity (40-950 uS. cm^{-1}). Due to higher ion-solubility of finest particles, the electrical conductivity of water rises with increasing frequency of silt and clay in pulverized and/or highly weathered rocks. This also depends on dimension and kind of pathways of groundwater. A system of gently dipping (nearly horizontal) planes associate the sliding surfaces, a framework of steep (nearly vertical) joints and fissures cross through the landslide-deposit. Waters influenced during infiltration through moraines leaved out of consideration. Temperatures and pH of waters seems nearly constant within the aquifer of the landslide-deposit.

The method applied at Tsergo Ri was helpful for

* detecting the position of primary and secondary sliding surfaces, i.e.

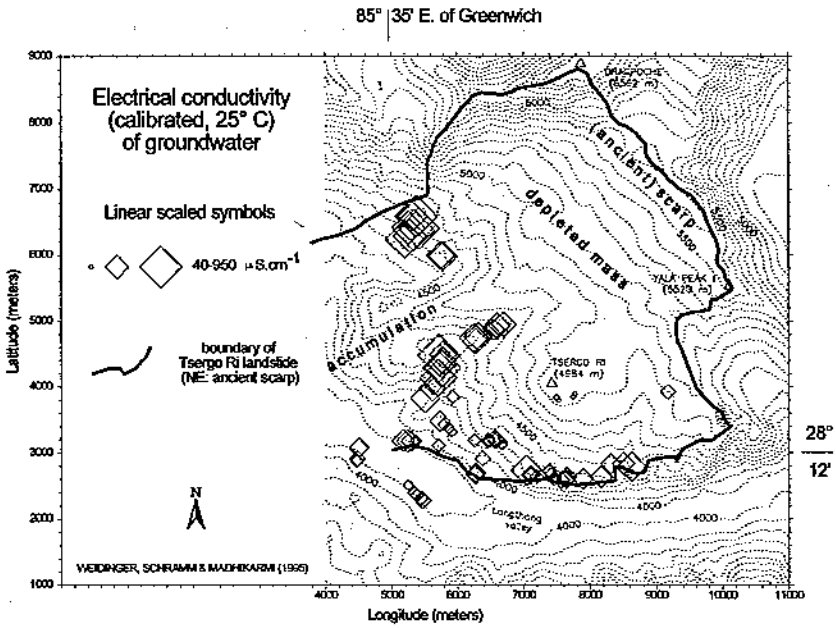

Fig. Electrical conductivity (calibrated, 25°C) of groundwater.

hyalomylonitic horizons, especially in transition zones between the hanging wall of the landslide, hiatus and undisturbed ground.

* exactly delimiting of the recent zone of accumulation
* mapping 6 classes of rock quality (compact, jointed, fractured, shattered, cataclastic and pulverized) within the landslide-area.

Considering tolerable sample variances, the significant trend is evident all over the Tsergo Ri landslide-area (figure 1).

* Blocky NW-part low electrical conductivity or missing springs as a result of deeper drainage than the recent erosional surface.
* Gradually to top brecciated SE-part medium electrical conductivity.
* Cataclastic and pulverized rock masses adjacent to strike-slip-faults (triggered during sliding) along Dranglung Chu valley: highest electrical conductivity.
* Remnants of landslide material in the N-part, affected by bi-directional extensive stress: highest electrical conductivity.

Thus, the simple method - qualifying uniform lithology and applied critically proved as efficient tool in landslide analysis and interpretation.

Support by the Austrian Science Foundation (FWF grant no. P7916-GEO and P09433-GEO) is acknowledged.

Selected References

Heuberger, H., Masch, L., Preuss, E. and schrocker, a. (1984): Quaternary landslides and rock fusion in Central Nepal and in the Tyrolean Alps.-*Mountain Research and Development, 4, 345-362, Boulder/Colo.*

Reddy, S.M., Searle, M.P. and Massey, J.A. (1992): Structural evolution of the high Himalayan Gneiss sequence, Langtang Valley, Nepal. - *In: Treloar, P.J. & Searle, M.P. (eds.): Himalayan Tectonics, Geol. Soc. Special Publ., no. 74, 375-389, London.*

Weidinger, J.T., 1992: Geologische Untersuchungen im Bereich der Großmassenbewegung von Langthang - Nepa. - *Unpubl. Thesis, Naturwiss. Fak., Universitat Salzburg, 100 p., Salzburg.*

Weidinger, J.T. and Schramm, J.-M. (1994): Tsergo Ri landslide (Langthang Himal Nepal) - short notes. - *J. Nepal Geol. Soc., 11, Kathmandu, in press.*

Weidinger, J.T. and Schramm, J.-M (1995): Tsergo Ri (Langthang Himal, Nepal) -Rekonstruktion der "Palaogeographie" eines gigantischen Bergsturzes. - *Geol. Palaont. Mitt. Innsbruck, 20, 231-243, Innsbruck.*

Some Engineering Geological Properties of Weak Siwalik Sandstones at Kalabagh, Pakistan

M. H. MALIK
Institute of Geology, Pubjab University, Lahore, Pakistan

Weak sandstones of the Siwalik Group (Miocene-Pliocene-Pleistocene) in Pakistan were studied to investigate the relationship of their fracturing and geo-mechanical behaviour with their petrology and geological history.

Field studies reveal variations in strength between adjacent faults whose magnitude can be attributed to effective stresses during burial. Relations between frequency of fractures and bed thickness, grain size (lithology), and distance from faults were determined.

Suitable sampling and testing techniques were developed for successful use in these weak Siwalik sandstones.

Laboratory tests indicate that strength of the sandstones is more related to individual beds (i.e. depth or the effective stress in each lithology) rather than petrology. Laboratory values for permeability vary more convincingly with depth than with other textural or mineralogical characters.

A recurring relationship between strength and permeability with depth implies a close relationship of these parameters with burial and uplift, i.e. recent geological history.

Role of Weak Soil in Slope Stability Calculations by Finite Element Method (FEM)

M. H. RAHMAN
Department of Geology and Mining, University of Rajshahi, Rajshahi, Bangladesh

In this paper an attempt has been made to illustrate the problem of landslide and slope stability of the non-homogeneous slope. The slope model consists of three type of cohesive soil having different values of modulus of deformation, poisons ratio, cohesion and bulk density. The height of the slope, 30 meters and the angle of the slope, 45^{o}, have been considered and this type of slope is the most common and widely used for the open-pit mine of different countries of the world.

The soil parameters which were used for the slope stability calculations were obtained by the Unconfined Compression, Triaxial Compression and the Direct Shear Box tests performed in the laboratory. The Computer calculations were done by using the Finite Element Method and the result includes the distribution of stresses, displacements as well as safety factor of the slope stability. The values and distribution of all stresses are greatly influenced by the presence and situation of the layer of weak soil in the slope model.

The satisfying results of the slope stability analysis of the non-homogeneous slope lies mainly in a proper engineering-geological recognition of the slope and evaluation of the Physico-mechanical parameters of soil including their natural changeability.

Landslide Study for Appropriate Counter Measure

B. TIWARI and I. KITAHARA
Water Induced Disaster Prevention Technical Centre
Kathmandu, Nepal

Dramatical variation in topography from low lying areas of the Gangetic plain in the south to Higher Himalaya in the north within a very short horizontal distance of 90 to 120 km characterizes the physical condition of Nepal. Improper land use in such hill slopes, either due to rapid population growth and poverty or due to lack of education, deforestation etc. has increased the landslide hazards more and more everyday. Such landslides have affected most of the expensive infrastructures of the country such as road projects, hydropower projects, irrigation projects and other related projects. Due to lack of expertise, budget and experience, very little attention has been paid to this aspect during the planning, designing and construction phases of such infrastructures. Department of Roads, HMG/Nepal has to spend huge amounts of its fund to clear off the materials deposited due to landslides.

Although Nepal has suffered loss of many lives and huge properties due to the landslide hazards every monsoon season and national newspapers print landslide news everyday, data and study on these landslides are very scarce. Landslide planning and investigation has still not been practised in concerned organizations of Nepal.
Realizing these aspects, DPTC was established on October 1991, under joint effort of HMG/Nepal and Government of Japan to strengthen the capability of HMG/Nepal to cope with water induced disasters. Among various fields of DPTC, one of the major fields of study is landslide.

DPTC is working in the field of landslide since its establishment in various aspects. A data base format is established to have a good landslide inventory. To investigate various types of landslides in the country, four landslide areas were selected as landslide model sites. Many of these were on the request of Department of Roads of HMG/Nepal. Besides this, under the request of different organization DPTC have studied various landslides in the country and submitted the proposals.

For a sound investigation and research work in the field of landslides, the centre is equipped with various types of equipments and laboratories, donated by Government of Japan.

To have a good co-ordination among different line agencies working on landslide, various types of meetings are being organized. To strengthen the capability of the Nepalese professionals, various types of training on landslides are being conducted regularly. To make the people aware of landslide disasters, various types of programmes are being launched in different districts of the county.

Study of Landslides Along Naini Tal-Kathgodam Highway

A. K. SHRIVASTAVA and V. JHINGRAN
Department of Geology, University of Delhi, Delhi, India.

The 45 km stretch of Nainital-Kathgodam highway is faced with a severe problem of landslides both during and after rains. Four major geological formations are seen along the road, namely :- Siwalik, Nagthat, Blaini and Krol. The frequency of landslide is maximum in Siwalik sandstone and minimum in Krol limestone. All the slides in Siwalik Formation is of planar type. Slabs of Siwalik sandstone and boulders have moved down under the influence of gravity (as at Dogaon) and have uprooted trees along slope. Water seepage through the discontinuities in Siwalik sandstone has formed slurry and is serving as potential slide surface for the overlying rock. Some of the landslides in Siwalik sandstone are caused primarily due to removal of toe support, like those seen near Dogaon. A wedge type of failure is seen in Siwalik sandstone near Joielikot.

Nagthat formation which comprises of phyllites, slates and quartzite shows debris fall.

However at Nainital-Almora bifurcation, a planar slide is seen in phyllites.

In Krol limestone very near to Nainital, huge debris fall is observed; width of debris is estimated to be about 4 kms. Vegetation at the crown of slides is sparse.

Unplanned construction of road leading to destabilisation of slope is the main cause of landslides along this road. In addition to this, overgrazing, reckless deforestation for timber fuel and fodder have lead to a number of landslides. Upslope extension of cultivation and settlement is yet another cause of landslide. In order to check this natural hazard, certain engineering works has to be done along the road. This would include planting coirnets firmly in the direction of water flow in which the lower end of net need to be stabilized by 20 cm long u-nail at 30 cm interval. This would be useful in preventing debris fall as in Krol limestones and Nagthat phyllites. Drainage control is the most effective and least expensive method and may be used for slides occurring in limestone and phyllite.

Gabion and buttress reinforcement wall can be constructed to prevent slides in Siwalik sandstone. Rock bolt and anchor may also be useful for Siwalik formation. In addition to this, joint in Siwalik sandstone must be grouted or covered with impermeable material to prevent sliding along joint planes.

Land System Evaluation and Geo-Environmental Impact Assessment of Pagladiya Detention Dam Project, Assam, India

RAVI. K. SINHA

Geological Survey of India, Patna, India.

As a part of geo-environmental impact assessment of a 30 m high and 25 km long earthen dam across the river Pagladiya in the pre-construction stage, the landscape of the basin has been categorised into two land systems viz. (1) Pagladiya Ridge Valley System, (2) Pagladiya Alluvial Plain System.

The Ridge Valley System of the basin is expressed as structural ridges and valleys constituting the Siwalik hills and Lesser Himalayan ranges.

Pagladiya Alluvial Plain System is divisible into the following four land form units viz. (1) Piedmont zone, (2) Dhamdhama surface, (3) Tamulpur surface and (4) Recent flood plain. They include the detention dam, the reservoir and the command area.

The said land units are characterised by an intricate assemblage of relict fluvial signature like backswamps, levees, abandoned channels, buried channels, cut-off meanders, terraces etc.

The alluvial land system is not only in a state of constant interaction with dominant fluvial processes operative within the framework of a distinct neotectonic activity but also has been a site of intense anthropogenic activity, mostly in the form of a rural urban growth, agricultural practices, construction of road and rail, dam and embankments, brick klin etc. Sixth order stream Pagladiya and its tributaries have been a source of recurrent floods, frequent channel oscillation and heavy siltation generally in response to past earthquake (indicating neotectonism) and are in a state of incision in certain stretches or aggradation in others.

The other inherent geo-hazards identifiable in this land system include (1) bank erosion, (2) water logging due to drainage congestion, (3) gully and rill erosion and (4) siltation.
The proposed dam across Pagladiya to check floods, and to meet irrigation requirements is an anthropogenic process resulting in creation of an artificial lake. This impounded water along with its system of canals will interact with the natural and other anthropogenic processes operative there to induce or aggravate the following geo-hazards:

(1) Siltation of water bodies, (2) Erosion by Pagladiya and its tributaries following destabilization of hydraulic gradient, (3) Water logging due to rise in water table in the flanks and downstream of reservoirs and the command area, (4) Failure of gully control structures already operational to combat gully erosion downstream of the proposed dam, due to rise in groundwater and creation of uplift pressure, (5) Initiation of fresh phase of reaction between geomorphic processes and

anthropogenic processes in the proposed rehabilitation centre for over 10,000 outstees (6) Enhanced flood propancity in the lower reaches due to imbalances in water table and backflow of the Brahmaputra when in spate.

The suggested remedial measures include extensive use of groundwater and surface water through deep tubewells and lift irrigation for multiple cropping. This will lower the otherwise shallow water table, reduce the flood intensity and frequency and will check water-logging.

Other measures include intensive afforestation in the upper and middle reaches of the river, wider application of gully control projects, destabilization of bars, stone apron at the bank erosion sites, enhancing the drainage density and regular monitoring of the landforms and processes.

Bihar-Nepal Earthquake of August 1988 : An Account of Damages in North Bihar Plains

R. K. Sinha, K. K. Sinha, M. Sinha, M. W. Haque and B. S. S. Reddy
Geological Survey of India,Patna, India.

On August 21, 1988 just before dawn, an earthquake of magnitude 6.4 on Richter scale awoke the half asleep people in Bihar and Nepal by its strong tremors. With its epicentre located in the Siwalik foothills of Nepal at 26.72°N. Latitude and 86.63°E. Longitude, it rocked and severely devastated extensive areas in eastern Nepal and north Bihar plains. Over one thousand people were reported to be killed and about 50,000 mud and brick houses collapsed in the worst affected region. In India, Madhubani and Darbhanga were the two worst affected districts while Saharsa, Sitamarhi, Samastipur, Khagaria, Muzaffarpur, Vaishali, East and West Champaran, Saran, Munger, Madhepura, Purnia and Patna also suffered damages to varying extents. The paper describes, in brief, the nature and extent of damages to various types of dwellings and the ground itself by this earthquake which were systematically recorded by the authors immediately after the catastrophe.

Sprouting of sand mixed water through numerous vents were a common sight in Laxmipur, Jaynagar, Rajnagar, Khajauli, Khutauna, Laukaha, Bhupatti, Babubarhi, Simra, Harri, Jhanjhatpur, Phulparas, and Laukahi localities. Ground fissures and minor cracks were also noticed in these areas in cultivation fields, villages and even on metalled or unmetalled roads. Significant and prolonged emission of dirty white fine micaceous sand with water was invariably associated with such features. Longest ground fissure, approximately 600 metres long and about 30 centimetres wide, was noticed in Bhupatti village. This fissure trending N 35°E was located in a mango garden and it was found extending in agricultural fields, passing right through the rural settlements. At times the sand gushing through liquefaction were so forceful that it even uprooted huge green mango trees. One such incident has been noticed and photographed in Khajauli in Madhubani district.

The worst affected terrain constituted predominantly a rural segment with majority of dwelling units of types C and D only which consist of weak structures like old brick houses with poor workmanship, ordinary construction material and no design to resist horizontal forces and still weaker mud houses with thatched roofs. As a result, thousands of mud houses and old brick houses totally or partially collapsed while cracks in the walls, roof and floors were so profusely developed in many other houses that these remained no longer safe for habitation and the people were forced to stay outside even during rains. Such cracks were further enhanced due to repeated aftershocks. 'B' type dwelling structures constructed with relatively good workmanship and construction material like R.C.C. and steel but again without design to counter horizontal forces developed irregular cracks in walls. 'A' type of houses are rare in the area under reference however, civil structures like dams, barage, reservoirs and irrigation canals in north Bihar escaped any damage due to this earthquake. Some minor cracks were developed in the Raj Bhawan at Patna also. In Khutaun pyramidal dome of the Radha Krishna temple fell down intact from the roof top in southward direction.

Systematic and scientific recording of all possible damages in entire area by this earthquake was felt necessary specially for isoseismal studies and its comparison with that of 1934 earthquake of north Bihar. Based on the account of earthquake damages in different areas, isoseismal map, of Bihar-Nepal earthquake for Bihar part has been prepared. This also helped in delineating various zones of different intensities around the epicentre. The results thus obtained show difference from the corresponding facts for the 1934 earthquake of north Bihar.

Effect of Pollutants (Dust) on Monuments of Delhi

A. K. PATHAK
Department of Geology, Delhi University

S. K. SINGH and R. K. SINGH
Biosphere Sustenance Society of India, Delhi

The historical monuments are one of the inherent part of our culture. Delhi has lots of monuments depicting Mughal and British architecture. They are made up of varied rock types such as sandstone, limestone and marble. Like human being, pollutants also take toll of historical monuments, magnificent statues, the beautiful work of art because stones also undergo decay leading to "stone cancer".

In this paper Delhi is delineated into four zones; taking Lal Quila and Jama Masjid in the north; Qutub Minar in the south, Humayun's Tomb in east, north and south blocks including central secretariat in the west.

The study shows the following effects of pollutants on monuments : In Marble :(a) Lack of lustre, (b) Ample dust deposited on stone surface, (c) A thin black layer and tiny black spots are noticeable, (d) The dust samples collected showed presence of soluble salts. In Sandstone : (a) Along the thin lamella of sedimentation exfoliation is distinctly visible, (b) Black encrustations are present in patches.

All NGOs should join hands with Archaeological Survey of India to encourage citizens to curb pollution and save our precious monuments.

Zinc-Lead Mineralization in Ganesh Himal Region, Central Nepal

J. R. GHIMIRE, R. K. KHADKA and C. K. CHAKRABARTI
Nepal Metal Company Limited, Kathmandu, Nepal

Carbonate hosted zinc-lead sulphide Mineralization of economic significance occurs in Ganesh Himal region, Central Nepal. The area lies in between 3,700 m and 4,900 m above msl. The mineralized bodies are situated very close to the Main Central Thrust. The Mineralization occurs in crystalline saccharoidal dolomite within a repetitive sequence of garnetiferous mica schist, quartzite, calcareous schist and amphibolite. These rocks (along with the ore) are folded into an anticlinorium and a tight synclinorium, and has suffered almandine-amphibolite-facies metamorphism and intense deformation during Himalayan Orogeny. Discontinuous band of graphitic schists occur below the mineralized crystalline dolomite. Confined to a single carbonate stratum, the Ganesh Himal zinc-lead ore appears to be of syn-sedimentary origin and subsequently exposed to metamorphism. Out of six occurrences in this area only one at Lari is explored extensively. Detailed investigations have confirmed more than 1 million tonnes of ore reserve containing about 16.4% zinc, 2.5% lead and 32 grams per tonne silver. The ore is rather simple. It is chiefly made of sphalerite, abundant pyrite, subordinate galena and pyrhotite and rarely chalcopyrite. X-ray diffractometry suggests possible occurrence of pyrargyrite. Ore texture indicates that recrystallization of sulphides took place probably at high temperature condition. Zinc-lead ratio is approximately 6.5:1, with recoverable silver and low cadmium. Trace element concentration is rather insignificant.

Mineral Resources and Geo-Environment in Nepal

D. P. MADHIKARMI
Department of Mines and Geology
Kathmandu, Nepal

When we talk about mineral resources, our mind is quickly diverted to metallic mineral deposits. Famous Chinese traveler Huan Shiang had reported that Nepal exported copper and iron to Tibet many decades ago. To develop the mineral resources of Nepal systematically various organizations have been established, combined and terminated. Based on 63 years of experiences of national geoscientists, advisors and UN experts, the Kingdom of Nepal has divided into five belts of different mineral potential. Major fourteen different minerals have been shown in the mineral occurrences map of Nepal. Out of these minerals which one is most abundant in the Kingdom of Nepal? If we assess the achievements of the past 63 years of explorations by different techniques, we will find that our country is rich in Hard Stone, Gravel, Sand, Clay and Water. Even if we look at the world production of mineral resources, we will find that minerals needed to manufacture industrial machine, car, utensils, precious metals are of lowest production than the construction materials. Figure "Mineral Snake" of Prof. Lutting clearly indicates that Hard stone, Sand, Gravel are the highest produced minerals in the world in an annual basis. For growing expansion of cities and development of infra-structures a lot of construction materials are being consumed annually. To fulfill the shortage of energy and water for drinking and irrigation purposes, enormous quantity of gas and groundwater are pumped out annually. These minerals of high demand are being mined out haphazardly affecting our environment, socio-economic, as well as health. Mineral resources are limited and their demands are high, and so we have to save them for future generations also. If we do not think about it in time, the coming generations will have to suffer because of our mistake. It is true that without intervention into the natural environment, we cannot have the mineral resources for our uses. We must, therefore, try our best to fulfill our demand, but keeping our geo-environment clean, by adopting systematic techniques while mining these minerals of world's highest demand only in appropriate place.

Chemistry of Tourmalines in the Metamorphic Rocks of the Central Nepal Himalaya

S. M. RAI
Department of Geology, Tribhuvan University, Tri-Chandra Campus,
Kathmandu, Nepal
and
P. LE FORT
Institut Dolomieu, Geodynamique des chaines alpines (CNRS),
15 rue Maurice Gignoux, 38031 Grenoble, France

The occurrance of tourmaline in various tectonic units of the Himalaya is well known. The tourmaline is found in almost all the formations, from the Midland to the Tibetan Sedimentary Series, and in the Cambro-Ordovician granites of Lesser Himalaya to the Miocene granites of the Higher Himalaya. This work was undertaken to study the chemistry of the tourmalines in the metemorphic rocks from Midland to the Tibetan Sedimentary Series in the Annapurna-Manaslu region of Central Nepal.

The chemical composition of the tourmalines was obtained by the microprobe analysis. The chemical composition is presented in schorlite (Fe) - dravite (Mg) - elbite(Al) end member diagram. The variation in chemistry of the tourmalines in different types of rocks is found to depend on the composition of the host rocks as well as the grade of metamorphism. The results show that the Mg rich tourmaline (dravite) is found to be concentrated in marble, calcic gneiss whereas schorlite - elbite end member tourmalines are found in the pelitic gneiss, micaschist, quartzite and granitic gneiss, with little increase of elbite content.

There can be seen a relationship of the chemistry of the tourmaline with the grade of metamorphism in the Midland Formation. The Mg content of the tourmaline increases with decrease of Fe and Al content, from chlorite to kyanite inverted isograde. In the Tibetan Slab, the temperature is essentailly constant with decreasing pressure from the base to the top of the slab. With these variations, the composition of the tourmaline is found to be evolved with an increase of Fe and decrease of Mg and Al content.

The wider presence of the tourmalines in the Himalaya shows the trace of the circulation of the fluids during the evolution of the Himalayan orogeny.

Mineral Processing of Koga Feldspathoidal Syenite Complex, Northwestern Pakistan : Use in Glass and Ceramics

I. H. BALOCH
Institute of Geology, University of the Punjab, Quaid-e-Azam Campus, Lahore, Pakistan.

A.C. DUNHAM
Geology Dept., University of Leicester, University Road, Leicester, UK
and
M. N. CHAUDHRY
Institute of Geology, University of the Punjab, Quaid-e-Azam Campus, Lahore, Pakistan.

The Koga feldspathoidal syenite deposit has various amounts of Fe_2O_3 and alkalis. Experiments on mineral processing of the Koga feldspathoidal syenite complex are presented, to examine the possibility of its utilization in glass and ceramics. The Fe_2O_3 contents range from 1.17% to 4.5%, whereas alkali contents (Na_2O+K_2O) are from 13.14% to 16.34%. The processing of the raw material was more effective on -250 + 125 u size fraction; the total alkalis increase relative to the starting material and Fe_2O_3 contents decrease to 0.13%. Following chemical analyses of sieved and magnetically separated fractions of a number of representative rocks, it is clear that the Koga feldspathoidal syenite could be beneficiated to make commercially accepted material.

Mineralized Pegmatites of Shengus-Bulache Areas, Karakoram Range, Northern Areas, Pakistan

A. M. KHAN
Earth Resources Development Division, Engineering Consultants, Int. (Pvt.) Ltd.
Karachi, Pakistan

The mineralized pegmatites of Shengus - Bulache Areas of Baltistan district, Northern areas of Pakistan, produces beautiful crystals and mineral specimen of Aquamarine, Topaz, Tourmaline, Moonstone, Garnet and Apatite. The pegmatites are associated mainly with metamorphosed rocks of Precambrian Salkhala Formation and occur as sills, dykes, swell and pinch. Two types are common; the simple pegmatite and the complex pegmatite. The later show polyphase mineralization. The area is tectonically deformed and is located in the vicinity of the Main Mantle Thrust (MMT).

A Tribal Welfare Measure - Utility of Gemstone Resources From Parts of Andhra Pradesh, India

C. KASIPATHI and M. V. L. PADMAVATHI
Department of Geology, Andhra University, Visakhapatnam, A.P, India.

India has been well known since times immemorial as a store-house for a variety of gemstones. A variety of gemstones are reported to be localized remarkably in the Archaean granulite and high-grade Supracrustal sequences. Eastern Ghats of India is a major granulite belt in the country extended along Orissa, Andhra Pradesh and Tamil Nadu. Some of the granulitic rocks are also reported to occur in parts of South India, Madhya Pradesh, Bihar and Rajasthan. Simultaneously the said states are also popular as market centres for the gemstone trade. It is difficult to record whether it is fortunate or unfortunate, as the said gemstone resources are found to occur in the rugged, hilly surroundings of most of Indian tribal agency tracts. It can be taken as a blessing in disguise for the development of tribal communities in the years to come, if the government commits in a real pérspective. A case study from the Eastern Ghat region of Andhra Pradesh is taken up in this paper as a means of tribal welfare development.

Khondalite, charnockite, granite, leptynite, calc-granulite, quartzite and pegmatite are the important petrological members of Eastern Ghats, Andhra Pradesh. Some of the valuable gemstones like chrysoberyl, moonstone, tourmaline, garnets, sapphire and a variety of quartz are well identified in recent times in close association with the pegmatitic intrusives, which forms as a result of residual liquid injections within the khondalite group of rocks. The prolonged weathering of pegmatitic veins brought to light recently, the gemstone occurrences in these regions. Detailed investigations are under progress. These areas are mostly occupied by inaccessible rugged terrain, tribal populations and social evils. It is also to some extent difficult to take up the investigations fast. The time when these resources are evaluated properly by any geological agency or by the adjoining university earth science departments, it will be a boon for the welfare of the tribals. The systematics of the utility of the gemstones for the tribal welfare are presented in this paper.

Authors' Index

Instructions to Contributors

MANUSCRIPT: Manuscripts should be submitted in triplicate, neatly typewritten, double spaced and on one side of the paper only. In addition, an electronic copy in 3.5" floppy diskette either in WordPerfect 5.1 or MS Word for Windows is preferred. The journal will accept original scientific papers only in English and Nepali languages.

THE TITLE PAGE: The title page should comprise the title of paper, the name(s) of the author(s) and their affiliations. The paper should preferably be not more than 10,000 words. Words to be printed in italics should be underlined.

ABSTRACT: An abstract of not more than 150 words should be included at the beginning of the paper.

REFERENCES: References should be indicated in the text by inserting in brackets the author's name and year of publication. At the end of the paper it should be listed in alphabetical order. For example, Auden, J.B., 1934, Traverses in the Himalaya. Rec. Geol. Surv. India, V . 69 (2), pp. 133-167.

TABLES AND FIGURES: Tables and figures should be of printed page size (7"x5") and should be in camera ready form. They should be properly lettered and numbered. They may be subject to reduction to appropriate sizes. Hence, the letters inside the figures should be sized proportionately. Photographs with explanations must be in black and white, sharp and clear and should be printed on glossy paper. Only the illustrations which are most essential should be inserted.

ACKNOWLEDGEMENTS: It should be placed before the list of References.

REPRINTS: Authors will receive twenty-five copies of reprints free of cost. Additional copies may be ordered for purchase when proofs are returned to the editor.

SUBMISSION OF MANUSCRIPTS: The manuscripts and all the correspondences regarding the Journal of Nepal Geological Society should be addressed to the Managing Editor, the Journal of Nepal Geological Society, P.O. Box 231, Kathmandu, Nepal.

Journal of Nepal Geological Society

Registration No. 1/042/043
US Library of Congress Catalogue Card No.: N-E-81-91064

Published by: Nepal Geological Society, P.O. Box 231, Kathmandu, Nepal

Jagadamba Offset Pvt. Ltd. Patan Dhoka, Lalitpur, Phone: 521393