

Progress of Geodynamics Projects in Pakistan

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Pakistan occupies critically material position in the evaluation of Geodynamics of "Alpine-Himalayas Region". This fact is being realised by national and international workers engaged in this region. This being the case, Pakistani scientists have only recently started making serious efforts towards this direction. Nevertheless the programmes recently initiated by the Geological Survey of Pakistan for geological and geophysical investigations in collaboration with the foreign geological/geophysical organisations are contributing materially in the development of this subject in the country. As such Pakistan has just entered into meaningful understanding of geodynamics. Some of these programmes are specifically oriented to resolve the stratigraphic issues and structural framework in the northern and western regions of Pakistan which may ultimately be most helpful in the synthesis of Himalayan geology; while other projects of geophysical investigations are directly or indirectly related to the study of tectonic framework of Pakistan. The projects are briefly described below.

BIOSTRATIGRAPHY OF PALEOZOIC ROCKS OF NORTHERN REGION

The northern region of Pakistan is being thoroughly investigated to establish the Paleozoic/biostratigraphy. The most important features of this region are the excellent development of Paleozoic sequence and the presence of 'colliding continental suture'. Some of the projects are aimed at delineating faunal provincialism if any, and its comparison with faunas of the south.

An attempt has been made by Talent and Mawson (1979) to establish provincial heterogeneity of Asia due to coalescence of various continental blocks and to delineate the regions of Pakistan which were not formerly part of the Gondwanaland, and to delineate the Gondwanaland in and adjoining areas of Pakistan plus comparison made of faunas from both the areas of the Gondwana and neighbouring region.

The areas recently investigated include Nowshera, Khyber Agency, Hazara and parts of Gilgit and Chitral. As a result of new findings it is now known that all the systems from Proterozoic to Recent are present in Pakistan.

Khyber. Poorly known Khyber area of the North-West Frontier Province has been taken up since

1968 and its stratigraphic sequence and dates are revised on faunal basis. Revised mapping authenticated four Paleozoic formations. As a result, richly fossiliferous horizons were located for the first time in the region. From some units a large amount of faunal collection was made in detail. As a result the presence of Devonian, Early Carboniferous and Permian has been established. The results of the preliminary survey have been published by Khan (1969), Shah (1969, 1971), Tahirkheli *et al* (1975).

Nowshera. Discovery of the Paleozoic reef at Nowshera by Teichert and Stauffer in 1965 was the first important contribution towards the Paleozoic geology of northern Pakistan. Stauffer (1968) published the details of the rock sequence present in the Nowshera area, followed recently by various authors in the region. It is now clear that the entire stratigraphic section of Nowshera area has Early Devonian age with the exception of basal sphyllite which are dated as Late Silurian [Shah (1977), Talent and Mawson (1979)].

Hazara. Rocks of Hazara region particularly of Abbottabad area have long been disputed and debated for their age and correlation. The disputed stratigraphic sequence was thought to range in age from Silurian-Devonian to Triassic. Recent studies (Fuchs and Mostler, 1972) in this region have proved that all of these rocks belong to Early Cambrian. Important point resulted from these investigations assumes that although these Cambrian rocks have dissimilar faunal assemblage with those of other Cambrian of Pakistan yet they are contemporaneous.

Gilgit and Chitral. Work in Gilgit and Chitral has made considerable breakthrough in the poorly known stratigraphic chronology of that area. Fossil collections made from the best sections located in Mastuj, Baroghal valleys and Darkot region have confirmed the presence of rock formations of Permian, Late Carboniferous, Early and Late Devonian ages. The most important find made during recent years is the discovery of Ordovician rocks from the northern most territory of Pakistan. Samples collected by R.A. Khan Tahirkheli of the University of Peshawar and J.A. Talent and processed for conodonts by P.D. Molloy of Macquarie University, Australia revealed the presence of Middle Ordovician. Prior to this, there was no authoritative record of Ordovician anywhere in Pakistan (Talent and Mawson, 1979).

A JOINT PAKISTAN-ITALIAN PROJECT OF DEEP SEISMIC SOUNDING — GILGIT-KHUSHAB LINE

A deep seismic sounding profile was observed in Pakistan in August, 1975 under a joint (Pak-Italian) Karakoram Geophysical Project. The objective is to determine the subsurface crustal variation along the observed profile using seismic velocity distribution.

The seismic signals from the shots in Sango Sar Lake near Astore and in the drill holes near Lawrencepur were recorded by a team of Pak-Italian geophysicists along a profile from Ishkuman in the north to Lawrencepur in the south. These shots were also recorded by a network of seismic stations at Tarbela.

The signals received from Sango Sar Lake shot were poor and a reliable interpretation was not possible. As such, the shot location was repeated in August, 1978, under a joint Pak-Italian Project as described above. The data are being analysed in Trieste Institute of Geodesy and Geophysics. It is hoped that toward the beginning of 1980 the results will be made available.

The available records of the Tarbela network of seismic stations have been analysed. From the shot-point at Lawrencepur an idea of the basement surface corresponding to the individual observation station and the shot position (approximately at D/2) has been obtained. The Astore shotpoint furnishes an approximate idea of the thickness of granitic layer upto the Conrad and the depth to the Moho. Based on the available data it is concluded that the thickness for Moho varies from 35 km at Lawrencepur to 82 km near Ishkuman. These findings may, however, be treated as tentative (M.A. Mirza, personal communication).

CONTRASTING TECTONICS OF KIRTHAR AND MAKHRAN RANGES

A statement outlining the problem of contrasting tectonics of Kirthar and Makhran Ranges and other geological and geophysical approach to the problem have been given by Farah, 1972. Progress made in this project is outlined below:

- (1) Regional geological mapping; gravity and magnetic coverage of 1000 sq. km in Bela Axial Belt.
- (2) Regional gravity and magnetic coverage of 1300 sq. km in Muslim Bagh ultramafic complex.
- (3) Regional geological mapping; gravity and magnetic coverage of 3200 sq. km in Chagai Hills region starting from eastern end.
- (4) A programme of paleomagnetic study of the

igneous complex of Bela and Muslim Bagh was started in October 1976, under the guidance and with the co-operation of Dr. Kees A. De Jong of Cincinnati University, U.S.A. Data is under process.

- (5) Aeromagnetic coverage of Bela and Chagai structural belts has been carried out with the assistance of Canadian International Development Agency (CIDA). Interpretation of the aeromagnetic in terms of regional tectonics is being done.

It is hoped that in near future it may be possible to collect the geological and geophysical data of the project area and to draw some inferences relating to geological phenomena that caused the radically contrasting tectonics of the linear orogenic belts of Baluchistan.

GEODYNAMIC EVOLUTION OF BALUCHISTAN; ROLE OF MAFIC AND ULTRAMAFIC ROCKS

This is a cooperative project of the geophysicists and geologists of the Geological Survey of Pakistan and some of the Universities in U.S.A. The project has been approved by the Government of Pakistan and the National Science Foundation, U.S.A. The project started in 1977. Its aim is to increase our knowledge of the geodynamic evolution of Baluchistan, i.e. the geological evolution in terms of large horizontal movements of parts of the earth's crust, generation of crust and destruction of crust. The goals of the project will be achieved by an exhaustive study of the mafic and ultramafic rocks of Baluchistan. The topics included in the research are tectonics, paleomagnetism, geochemistry and geochronology. The project is deemed important because geological and geophysical knowledge on Baluchistan is of fundamental importance for the correct understanding of the genesis of the Alpine-Himalayan ranges. The knowledge of geodynamics of Baluchistan will also improve the evaluation of the mineral potential of Pakistan as it has been shown that the important mineral discoveries so far made are closely related to the geodynamic processes.

The result of the project activities during the last two years are compiled by Farah and De Jong (1979). Geological Maps on 1 : 50,000 scale of Alam Beg and Mashki Chah, Chagai, Baluchistan (Arthurton *et al.* 1979). The publication on geodynamics (Farah and De Jong, editors, 1979) contains 27 papers from Pakistani and foreign experts.

First five papers deal with tectonics of Pakistan, the points pertaining to Geodynamics of Pakistan have been described in relation to the adjoining regions. This section is followed by six papers explaining

geology and geophysics of northern Pakistan. The important information drawn in this section is that of hitherto little known Kohistan area. Recent earthquake of 1974 in Patan, its causes and effects are described and future hazards are forecasted. Papers 12 to 17 deal with geology of ophiolite complexes of Pakistan with the time of their emplacement in Baluchistan. The last section mostly on geophysics, dealing with up-to-date tectonics of Pakistan has been included, a total of fifteen seismotectonic provinces have been distinguished. It is deduced by some that the subduction was not uniform in its process. The characteristic features including oroclines, arcs and lateral faults syntaxes in Pakistan are conceived to have originated as a result of convergence of the Gondwana and Eurasia plates.

In short, this publication presents a host of information for the workers on this region to conceive and design better footings in the perfection of geodynamics.

Recently A.H. Kazmi (1979) has compiled a Seismo-tectonic map of Pakistan. This map gives details of structural configuration of the country and shows active as well as dormant faults resulted from diatrophism.

Last but not the least is a compilation made recently by Gauhar *et al.*, (1979) which outlines the broad plate tectonic and metallogenic framework of Pakistan. This is largely based on the work done under the GSP — USNSF joint project of Geodynamic evolution of Pakistan and the metallogenic studies carried out under the auspices of the UNDP. While presenting a preliminary analysis of different metallogenic provinces of the country, some observations have also been made in the report about the possible future mineral prospects of Pakistan.

BIO-STRATIGRAPHIC STUDIES OF CAINOZOIC ROCKS OF PAKISTAN

Paleogene and Neogene continental deposits of Pakistan and their vertebrate fauna is considered vital to synthesize evolution and mammalian biostratigraphy. The sediments are increasingly important for the study of Asian climatic and tectonic history. The projects, aimed as such, were conducted by the Geological Survey of Pakistan in collaboration with Harvard and Yale Universities, U.S.A.

The investigations made by G.S.P.—Harvard team in the Paleogene and Neogene continental deposits of Pakistan has been comparative in nature. Certain tentative conclusions drawn from the research are presented below.

Miocene Deposits: Neogene vertebrate fossils were collected from several localities in the northern and western Potwar area. The collection includes six families of rodents, among them Sciurids, glirids and cricetids were not reported previously from South

Asia. The most abundant rodents, however, are Ctenodactylids; Ctenodactylids specimens share features not only with other Siwalik specimens previously described as *Sayimys*, but also with *Sayimys obliquidens* from Western Kansu. Cricetids are also common in the collection. Some species are quite similar to both Europe and North America. A large collection of Murids from Pakistan is considered important for comparison with the abundant Vallesian murids of Europe.

Similarly, the occurrence of yet older equid, probably *Hipparion*, in this fauna is of particular importance for both Siwalik and intercontinental biostratigraphic correlations (Hussain, *et al.*; Progress report 1979 unpublished).

Eocene Deposits: The important findings on rodent relationships and paleobiogeography have recently been complimented by equally significant discoveries of Eocene large mammalian fauna and their interpretations add dimensions to paleogeographic analysis of the South Asian Paleogene. Most earlier authors have almost always looked to Mongolia and Burma and ultimately to North America for comparisons. The newly discovered fauna of abundant and diverse cetaceans, the oldest known proboscidean, and a conodont artiodactyle of possible European affinities now necessitates comparisons with and reference to the western Tethys. Hussain *et al.*, (1979) observed that the cetaceans and moeritheres are the strongest link to the western Tethys. *Moeritherium* is known only from late Eocene of Egypt; it is clearly more derived than is *Anthracobune pinfoldi*. This may move the differentiation of the Proboscidea from the generalized tethythere stock back at least to the Early Eocene, and inserts South Asia as a reasonable geographic source area. *Kbirtharia*, which we now consider to belong to the Helohyidae, seems to have its closest affinities with animals such as *Cebochoerus* of the middle and late Eocene of western Europe. The workers hoped that further study of the *Kbirtharia* skull now available may clarify the relationships of this genus. On the other hand there are links to the Eocene of Central and Eastern Asia. Two distinctly different brontotheres are now known from Pakistan. Brontotheres were abundant and diverse in the Eocene of Mongolia and the later Eocene of Burma. Also *Gobiobryus orientalis*, previously known only from the later Eocene of Mongolia, is now traced in Pakistan.

From the studies of fauna, Hussain (1979, progress report unpublished) concludes that perhaps, during its northward drift, the South Asian sub-continent passed near enough to the eastern coast of Africa for a quasi-continental connection to have existed. In this case, Paleogene North Africa and South Asia may well have possessed a largely common fauna, and the African influence on the South Asia Paleogene could have been quite direct.

GSP—YALE PROJECT:

Mio-Pliocene: Pilbeam *et al.* (1977) briefly discussed correlation of the faunas from Pakistan with those of Eurasia and Africa. Since then the progress in the understanding of intercontinental correlation has further been made. According to David *et al.* (1979 unpublished) several important groups (bovids, suids, rodents) give the impression that there are a few rather distinct faunal blocks separated by periods of rapid change, although the picture from other groups (carnivores) suggests a series of more gradual and less clear-cut changes. The work is in progress and it is hoped that rate of population movement and mode of faunal change will be better understood in the near future.

Briefly the workers observed that faunas of Kamlial and Chingi formations (11-15 m.y.) show a number of similarities to Astaracian faunas in Europe, barstovian faunas in North America and East African middle Miocene faunas. Thus rodent faunas with cricetids are similar to those in Europe (Anwil in Switzerland, for example) and North America dated at around 11 to 15 m.y. Three or four species of bovid are identical to those from Fort Ternan and Ngorora in Kenya, Africa, with an age range of 14 to around 10 m.y. Suid resemble Astaracian forms. Similar ties are to be seen in some other groups (i.e. proboscideans).

At that time resemblances of Pakistan and other South Asian faunas were fairly general, showing ties to North America, west and central Eurasia, and Africa. Possibly we are witnessing a period of moderate endemism disturbed by a faunal change, involving both emigration and immigration, as noticed in Dhok Pathan Formation. Several groups distinctly exhibit changes, among them are primates, carnivores, suids, bovids and rodents.

It may be emphasized that simple correlation outlined above is tentative and it may well need modification in the direction of increased complexity.

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