Origin and growth of the Indian ocean between India and Australo-Antarctica are interpreted from Albian onwards due to distanting between relatively stable Indo-Afnca and southward drifting Australo-Antarctica and associated increasing ammonoid dissimilarity

Common presence of Placenticeras among India, S Africa and Madagascar during Turonian-Comacian does not permit any distanting apart of these regions, while Australo-Antarctico-America continued to distant away southwards from Indo-Afnca At any point of time during this interval the distance between the Indian East Coast and West Australia remained greater than between South Africa and Patagonia

India inclusive of Madagascar if at all drifted northward, was with much slower speed up to Campaman

Origin of the Indian West Coast is interpreted in Maastrichtian in view of rather unique ammonoid compositional character with presence of highly diverse species not known from other Gondwana constituents

Oceanic isolation of India is concieved only from Maastrichtian onwards with oceanic separation of Madagascar, and rapid drift of India northward henceforth only from Maastrichtian onwards

APPLICATION OF GEOPHYSICS FOR THE STUDY OF THE STRUCTURE OF THE HIMALAYA AND TIBET*

TS BALAKRISHNAN
8, Sneha Sadan, Dr Ambedkar Road Matunga, Mumbai - 400 019

EXTENDED ABSTRACT

The topography of the country has been completely mapped by the Survey of India Similarly, the geology as seen from surface outcrops of rocks has been extensively mapped by the Geological Survey of India Similar maps of the subsurface however are not available This mapping exercise has to be carried out using geophysical data that has been acquired during the past 50 years or so by various organisations Gravity and magnetic anomaly maps lend themselves to useful interpretations of subsurface structure, but so far this approach has not been adequately exploited

Gravity and magnetic methods do not allow unique determination of depth to causative bodies For such information, the only route is through seismic surveys These are however slow and expensive and therefore complete detailed coverage of the whole country is impractical However, existing seismic data can be effectively used as a control in the interpretation of gravity and magnetic data Such an exercise has been carried out over the entire country and its environs and a map has been prepared showing the subsurface block structure of the subcontinent and its subdivision into segments A brief description of the part relating to the Himalayan region is given below

The main control for mapping the subsurface of the Himalaya consists of two deep sounding seismic profiles The first stretches from the Kashmir valley northwards across the Pamirs The second is a similar profile in the Nepal-S Tibet region upto the suture zone Both profiles show deep faults immediately to the south of the High Himalaya The Moho drops from around 35 km depth in the Nepal/Kashmir area to around 75 km in the S Tibet/Pamir area across these deep faults The subduction phenomenon near the suture zones is clearly brought out

In S Tibet, the stratigraphic column is broadly divided into two units The upper one has an average seismic velocity of 6 km/sec while the lower unit has a velocity of 6 4 km/sec We term these as the upper and lower crust In terms of velocities these correspond to the Sial and Sima, the former being acidic and the latter basic The interface between these two units can be observed all the way from Muzaffarpur in Bihar right across the Himalaya upto Tsangpo suture at depths increasing from 3 km in the former upto about 30 km in the latter We associate this with the Great Indian Detachment across which the crustal contraction due to the subduction process is accommodated The lower crust of the Indian plate along with the Moho below it is heavy and descends into the mantle and is lost by melting in the high temperature region The upper crust is too light to penetrate the mantle and crustal contraction is accommodated by the pile up of its parts along a series of low angle thrusts leading to the steady thickening of that

^*Special Lecture delivered at the Geological Society of India Bangalore on 28 JO 2003* element from south to north The thrusts mapped at the surface are parts of this system

It will be noted that the upper crust is dominated by the thrust system, while the lower crust is dominated by vertical faulting Both these systems are active in the subduction process

The striking feature common to both the seismic sections mentioned above is the major faulting across which the Moho depth increases from 35 km in the Indian side to around 75 km in the Tibet/Pamir side The sudden increase in crustal thickness leads to a decrease in the average density of the crustal column that in turn leads to an isostatic uplift of the Himalaya and Tibetan/Pamir plateau This sudden change in topography is conspicuous

The next problem is to establish the continuity of fault all the way from Kashmir to Nepal The parameter that has continuity between these two profiles as well as over the entire Indo-Gangetic plains is the Bouguer gravity anomaly A broad analysis of this data is presented below

The conspicuous feature of the anomaly is its steady decrease northwards from the Bundelkhand gneisses in Central India, across the Indo-Gangetic plains, the Himalaya, S Tibet upto the suture zone This is ascribed to the steady thickening of the low velocity/density sialic crust in that direction One can correlate the base of the upper crust with the decrease of gravity anomaly as a first approximation

Superposed on this broad regional gradient are narrow areas where the local gradient is particularly high We associate these zones with deep faults in the lower crust Comparing with the results of seismic surveys, it is found the areas of these large gradients correspond with the vertical faults of large throw in the lower crust and upper mantle It has bee mentioned earlier that they produce a sudden change in the crustal thickness between India and Tibet By mapping the zone of high gradients, one can identify the line separating the Indian and Tibetan crust's In Himachal Pradesh, this separates the Spiti Basin from the Lesser Himalaya In Kumaon and further east it separates the Almora crystalline nappe from the Inner Sedimentary zone of the Lesser Himalaya In Eastern Nepal, Bhutan and Assam, it separates the High Himalaya from the Lesser Himalaya As expected, the fault lies to the South/Southwest of the High Himalaya

A major element in Himalayan tectonics is the Pamir-Karakoram fault It has a large side slip movement of over 200 km and shifts the gravity low axis of Tibet northwards to the conesponding low in the Pamirs Similarly the B-N suture and Tsangpo suture in Tibet are shifted to the Shyok and Indus sutures in Kashmir Further, the line up of High Himalaya peaks is shifted from the Banderpunch Api axis to the Everest-Dhaulagiri axis The Tethys region of NW Himalaya has a NW-SE strike, while that of S Tibet has an E-W strike The dividing line is the Karakoram fault It can be traced into the Ganga Valley where it cuts off the Bundelkhand block and the Narmada-Son lineament at its eastern side

Control on Thrusts

The Himalayan Thrusts are controlled by the structural blocks of the subcontinent The Marwar block is immediately to the south of the Main Mantle Thrusts of the Nanga parbat region The NW Himalayas are controlled by the noithward extension of the Aravalli block The Kumaon and Eastern Himalayas are controlled by the extended part of the Bundelkhand block These blocks are overridden by thrusts m the Lesser Himalayan Region To the North/NE these blocks are adjacent to the India-Tibet crustal boundary

In Kumaon the Lesser Himalaya is divided into the Almora crystallines in the Indian crust and the Inner Sedimentary basin in the Tibetan crust

In Nepal, the Inner sedimentary basin of the Tibetan Crust is virtually in contact with the sub-Himalaya Further east, the crystalline thrust virtually covers the entire Lesser Himalaya burying even the Gondwana basin to its south

In the NE, a north trending spur of the Indian crust controls the Himalayan thrust and produces the Eastern syntaxis It is interesting to note that the oilfields of the Brahmaputra Valley are situated on this spur

Sub-Himalayas

The Lesser and Sub-Himalaya are separated from the continent proper by a deep sedimentary though stretching from the Potwar Plateau, through the Sub-Himalayas of HP and the northern part of the Ganga plains This trough is filled with Lower Siwahk and Murree/Dharamsala sediments laid in the Siwahk River

Compressive forces of subduction have thrown these deposits into anticlinal folds/thrusts giving rise to the Siwahk Ranges of Kumaon, Garhwal and Himachal Pradesh It is interesting to note that these folds extend subsurface into the Ganga Valley giving rise to the Sarda and Dhrang structures

In the east, north of the Shillong plateau the Peninsular block is directly overridden by the Himalayan thrust without the intervention of the Siwahk deposits

The above is a representative but very incomplete and compressed account of the information that can be derived from geophysical investigations in the subcontinent