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Some Aspects of Applied Geomorphology[1]

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I feel honoured to have been elected as the President of the 31st Session of the Indian Institute of Geographers. I am particularly glad that there has been a gradual progress in the publication of its journal and I am informed that the ICSSR – Indian Council of Social Science – has increased its contribution for the publication of the journal. The credit justifiably goes to the Members of the Council and the authors of the various papers published in the journal. The Department of Geography at the Bangalore University has been growing from strength to strength adding periodically new courses keeping up with the needs of the time. It has a very bright future.

I notice that, by and large, my recent distinguished predecessors have delivered their Presidential addresses through a scholarly textual material covering various aspects of their chosen topics. They were dealing with environment, water resources, and sustainable development the topics of deep concern for the society. The theme chosen for this Conference, namely Environment, Agriculture and Food Security in India is equally an important one in the context of what the country is passing through now. I am confident that the participants will present the results of their studies leading to some possible solutions for this problem.

Geography being an inclusive subject covering and borrowing from a number of subjects like environment, agriculture and food security, the theme of the conference, and having a link with everything under the sky, especially the surface of the earth, I shall concentrate more on this surface and less on other aspects of the theme of the conference. The world started worrying about the environment after it noticed in the pictures provided by geostationary remote sensing satellites, ozone holes in the late seventies (1978). In fact these ozone holes have induced a great concern and conscience of the whole world not only over the ozone depletion alone but also over a whole gamut of issues connected with the question of meeting the challenges of expected shortage of food and water for the masses.

Land is one of the most vital natural resources and is finite like most of the other natural resources. About 90% of food for people and livestock, fibre and fuel for livelihood come from this resource. With population estimated to increase from the present 6 billion to 8.5 billion by 2020, a large increase in food production is necessary. And this food must come from the same land out of improved agricultural practices and crops. That is why the accent in my address is on the surface of the land and the subject that deals with that surface i.e., geomorphology. For example, you have a clayey surface and sandy surface,

1. Presidential Address delivered at Indian Geographers' Meet, IIG Conference Banglore, Feb. 2010.

Fig. 1: Geomorphic Features of a semi-arid region Bellary, Karnataka, 1963

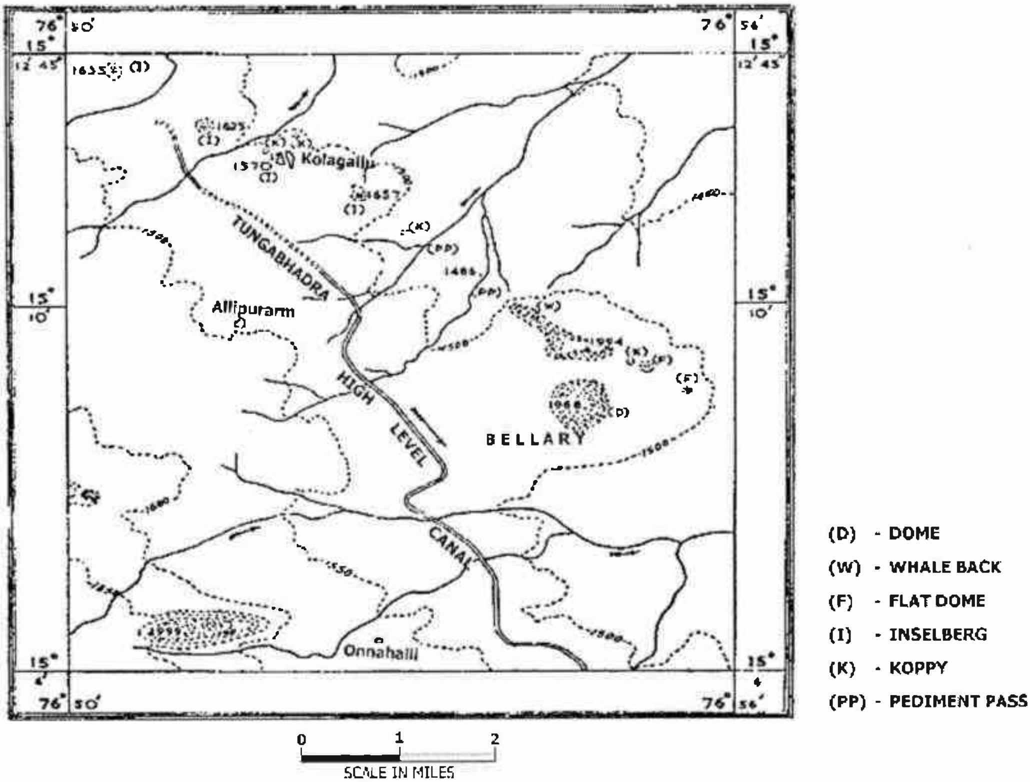


Fig. 2: Geomorphic Features in Godavari Delta, A.P.

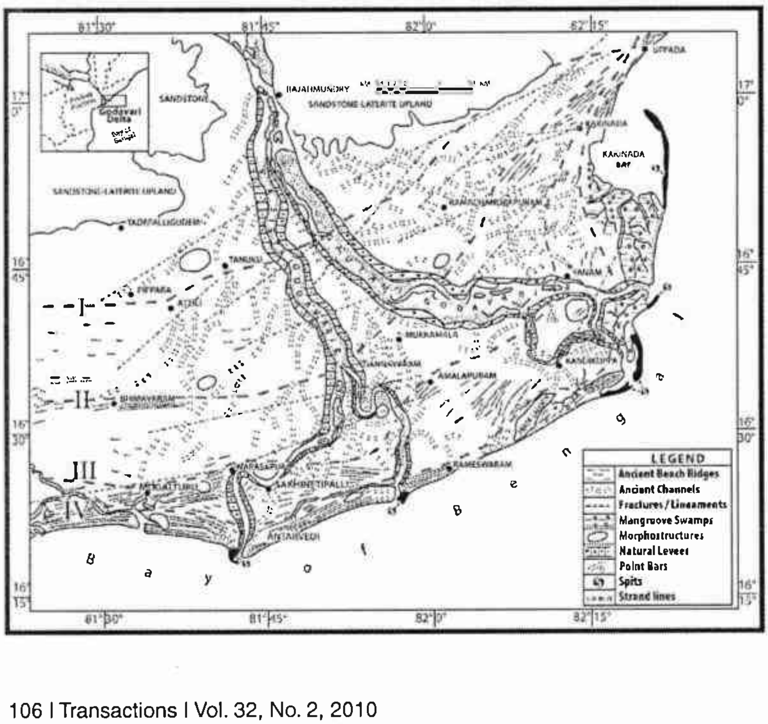
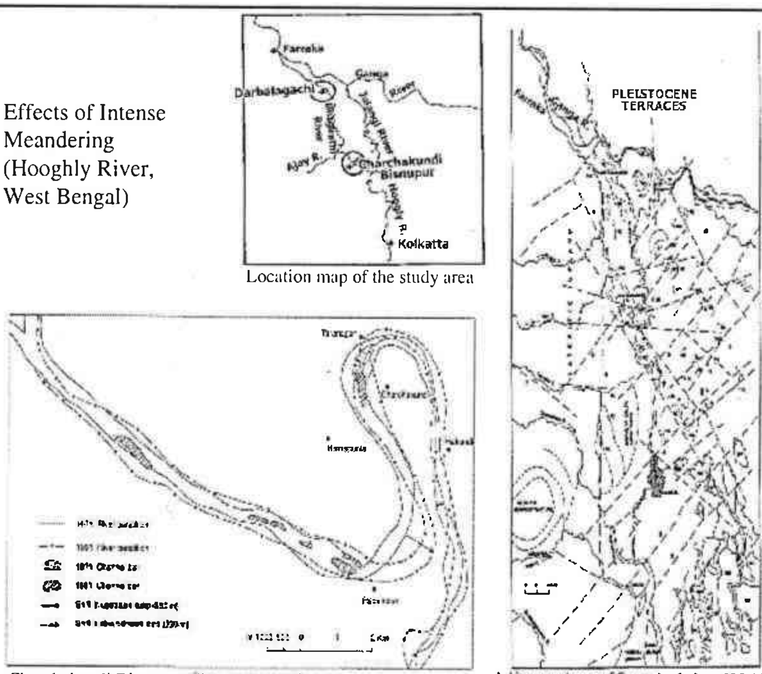


Fig. 3: Stages of meandering in loops in the Hooghly River, West Bengal

Effects of Intense Meandering (Hooghly River, West Bengal)

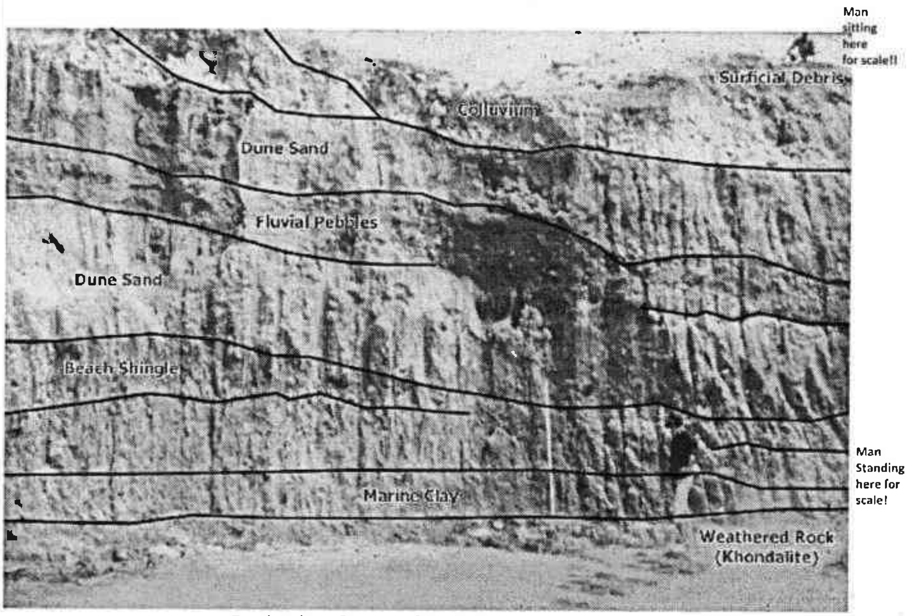


Location map of the study area

Charchakundi Bisnupur Change Detection Map (1971-1991)

A. Lineament map of Ganga basin from IRS-1A LISS-1 Satellite data. MG- Mangrove; CB-Channel Bar; SW-Swamp; OL-Oxbow Lake; MS-Meander Scar; PC-Palaeo-channel ------ 1,2 Lineaments with numbers.

Fig. 4: Sediment Facies in coastal Vizag Andhra Pradesh



Section in a Quarry of Steel Plant Area, Vizag the former fit for raising paddy and the latter fit for wheat; if these surfaces are used in reverse or used for both the crops, the yields would be less and cost of production more. Fitness and production capacities of different soils are different and landforms correlate very well with soil types. These are different on colluvial plain, alluvial plain, flood plain, natural levee field, over buried channels, because basically the texture and composition of the materials are different. That is why, there is a need now than never before to thoroughly understand our land first to plan for higher than current production from the same finite land, to provide food security to people and livestock.

During the 1960s to 1990s my research scholars, colleagues and self were concentrating in research in the narrow field of geomorphology at the Andhra University at Visakhapatnam in Andhra Pradesh. It may appear as though that geomorphology as it is known now dealing with the science of landforms, is perhaps only a little more than half a century old. But it should not be forgotten that naturalists and philosophers of yore, have in prose and poetry described landforms in different parts of the world in different languages, occasionally inferring the processes of their formation and evolution. Modern geomorphology, though not necessarily christened as such, can be said to have emerged from around the end of the eighteenth century and beginning of the nineteenth century. Vishwas Kale and Avijit Gupta (2001) have given a brief history of geomorphology and important publications of those from around 1500 A.D. to modern times on landforms, processes and tools used for the study.

It will be my endeavour now to drive home a point in research, whatever the field. Renowned scientists in this country are now embarking on a crusade to impress on the researchers a crying need to plunge into basic research in all the sciences, which have taken a beating since the advent of Information Technology and Communications, though they are no less important for the progress of the society.

A very few examples are being presented now, where, by and large, the goal was only to collect and analyze primary scientific data in the different branches of geomorphology. In almost all cases, sooner or later useful applications arose in each case. These may pertain to climatic (arid to semi-arid, glacial etc.), fluvial, coastal and even sub-aqueous morphology.

Geomorphic features of an area around Bellary in northern Karnataka, which is a semi-arid region, were studied and as a result domes, inselbergs, whalebacks, flat domes, koppies, pediment passes were all recognized in 1963. Incidentally it was noticed that close to these, excavation was in progress only in certain sections of the Tungabhadra High Level Canal, some sections almost abandoned for the time being (Fig.1; Vaidyanadhan, 1971). This was mainly because of lack of knowledge of the varying thickness of surficial deposits over pediments, pediment passes, bajadas etc., over which the route of the canal was aligned and the contracters did not anticipate the varying thickness of the overburden. The construction engineers at the site were duly informed of the action to be taken to circumvent the difficulties met with in the excavation process.

With a main objective of tracing the features in the prograding Godavari delta in Andhra Pradesh, aerial photographs were studied, and ancient channels, ancient beach

Fig. 5: Effect of Rip Current on a Swimmer

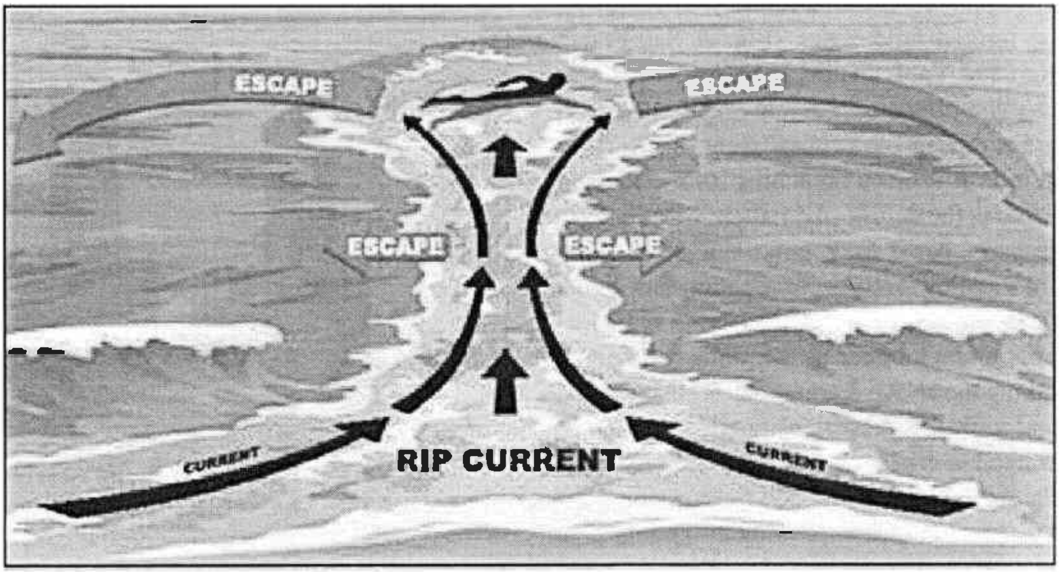
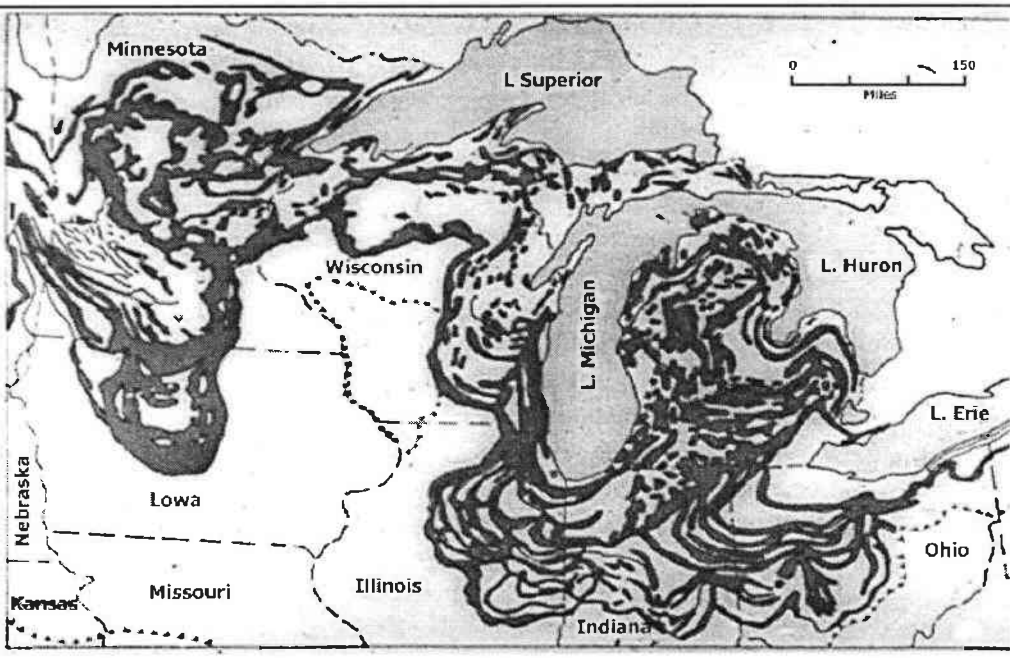


Fig. 7: Geomorphic features and sediments due to Continental glaciation in N.E. USA

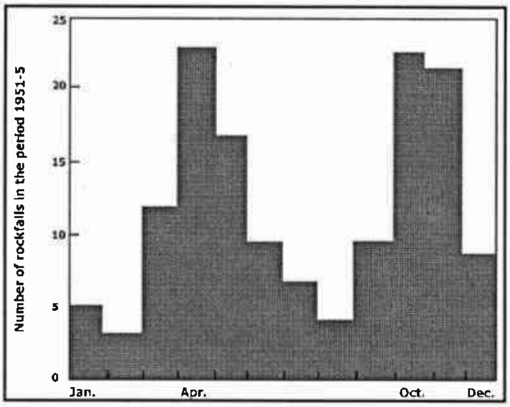


End moraines of Wisconsin-age glacial drift lobes in the midwestern United States. The end-moraine pattern is in heavy black. The hachured line is the drift border.

ridges, morpho-structures, lineaments and possible faults were identified, followed by limited field check (Fig. 2; Sambasiva Rao and Vaidyanadhan, 1979). These also enabled inferring possible major stand-still areas during the progradation of the delta (I to IV). When a breaching took place in a canal in the deltaic plain, there was flooding in parts. Need for regular supply of water for standing crops became paramount at that time. It was then that the above map was used and a number of locations were given taking the above features into consideration and with the successful tapping of ground water, the crisis was got over. Subsequently the same area was mapped by the Geological Survey of India demarcating the geomorphic units of marine and fluvial environments and inferring similar stand-still ancient beach ridges (Rangamannar and Pradhan, 1991).

Comparative study of planimetric changes of two meander loops in the Hooghly River in West Bengal was made using remote sensing techniques (Fig.3; Vinod Kumar and Asis Bhattacharya, 2006). Multi-date and multi-sensor satellite data were used, the earliest data being from that of 1971 toposheet and the latest being 1991 satellite data. It was found that whereas the one close to Dias-Balagachi in the upper part of the river, a little down from the Farakka barrage across Ganga River, showed shifts of 150 and 400 m in the two arms of the meander belt, in the case of Charchakundi-Bisrampur, further south in the river, the shifts were 950 and 250 m respectively of the two arms, over a period of 20 years. This difference is partly due to the tributary Ajay River joining the Hooghly just above the second meander loop, but also due to this meander loop being sandwiched between two NW-SE lineaments (faults?) along

Fig. 6: Seasonality of Rockfall in Norway, N.W. Europe



which minor movements might have taken place. This must be taken into consideration in executing any construction on the banks of the loops here, as any improper and hasty planning may result in hazards, like caving of the banks or unusual flooding.

Visakhapatnam Steel Plant in Andhra Pradesh is located about 20 to 25 km due SW from the city. Extensive excavations were made in many places for foundation purposes. One such excavation was around less than half a kilometer from the coast (Fig.4). Within about 6 m of thickness, sediments deposited due to marine, fluvial and aeolian agencies – marine clay and shingle beds, rounded pebbles and dune sands were observed over weathered khondalite rock, at the base. In an area further north in the coastal section of Visakhapatnasm city, close to the harbour, a lack of recognition of such intricate facies changes in the sub-strata in the construction of a hotel (Vikram) resulted in a slight tilt of the entire building, like the leaning tower of Pisa. Now it is stabilized by buttresses on one side and is being used by a business concern.

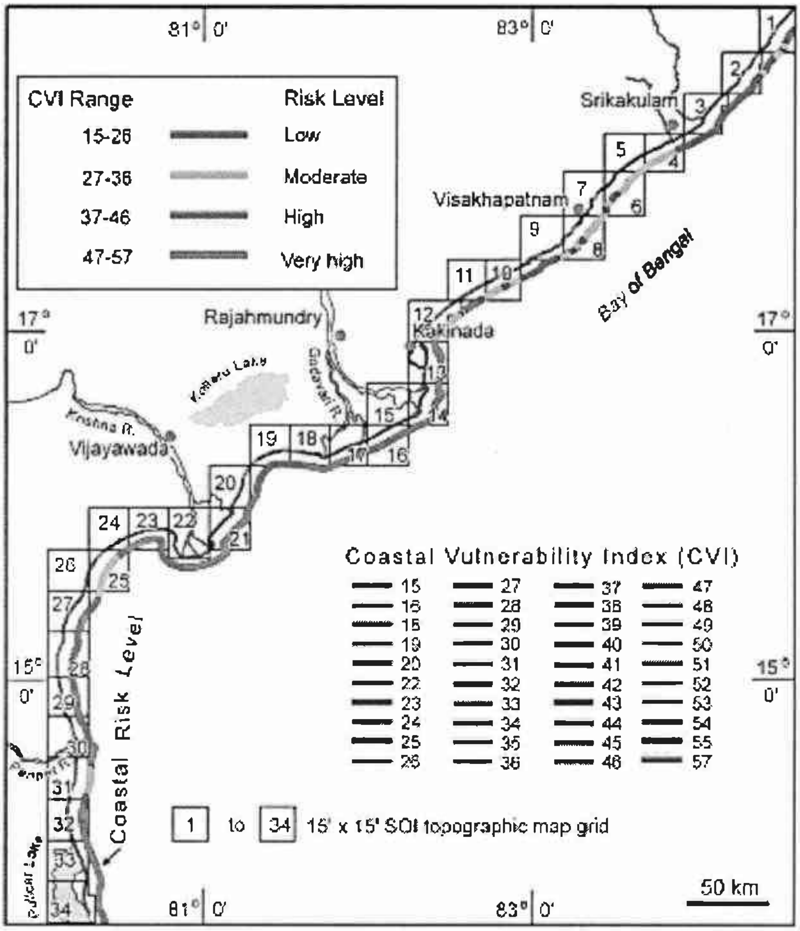
It will be noted that even in apparently minor but serious problems, knowledge of the morphology and processes involved saves one from serious hazards. A study of directions of flow of the eddies of a rip current along a coast, where there are sub-aqueous bars (Fig. 5; www.loving-long-island.com), clearly shows that a swimmer caught in it should not attempt to come back to the shore against the currents, which he often tries to do, but should try to escape sideways after going along the direction of the eddies for a distance, where they will dissipate. Such hazards can be avoided with a knowledge of such phenomena, the along a coast. Absence of this knowledge had resulted in the drowning of a few enthusiastic swimmers going for a sea bath along the Visakhapatnam coast.

A study was made in Norway in northwestern Europe of the seasonality of rockfall over a period of 4 years, January to December of 1951-1955 (Fig. 6; Bjerrum and Jorstad,1968). It was very clearly observed that the maximum rockfall during each of those years were during April-May and October-November indicating a climatic control of the processes involved. We are also aware of such variations in the mountainous regions of Himalaya and studies are being made to apply such knowledge of the morphology and the processes to protect property and life in those areas from possible hazards. The Border Road Organization in our country is now well aware of this seasonal hazard in the Himalaya and not only warns the travelers about the state of the roads, but also takes quick action in restoring the roads for free movement of traffic, when they are are covered with rockfalls.

A major part of northern hemisphere was affected by Continental Glaciation during the Pleistocene, from about 1.8 million years ago. Extensive areas, particularly in northern United States, were covered by those deposits during interglacial periods (Fig.7; Flint et al. 1959). Appropriate use of land covered by such deposits – essentially made up of moraines, eskers, kames, till plains etc. could be made only with a thorough knowledge of these deposits whether for construction purposes, highway planning, ground water resources, sites for wastage disposal, drainage etc. It is the recognition of the need for detailed study of such surficial deposits that led the United States Geological Survey to prepare 2 types of maps of 7 ½ minute quadrangle each on – (i) bedrock geology and (ii) surficial geology. In the earlier days our own geological maps represented most of the Quaternary surficial deposits with a flying bird symbol or if in colour, with yellow shading. Things have changed over a half a century and we can now see detailed geomorphic maps of the above period prepared both by professional organizations and academic institutions, on modern lines, mostly aided by remote sensing products supplemented by field work and they are now being used for purposes listed above with a greater confidence on the knowledge of the terrain and the sediments.

Global warming is the talk of the day. Not necessarily urged by this clamour, an attempt was made to estimate as to what would be the effect of a rise of sea level of about 0.6 m along 1030 km of Andhra Pradesh coast. The data collected were on (i) coastal morphology, (ii) coastal slope, (iii) shoreline change, (iv) mean spring tide range and (v) significant wave height. It is

Fig. 8: Coastal vulnerability index (CVI) and risk levels of different segments of Andhra Pradesh Coast



estimated that such a rise may displace ~ 1.29 million people located at 2 m elevation in 292 villages along this coast. The rise has been categorized as Low, Moderate, High and Very High (Fig.8; Nageswara Rao et al.2008). Even if there is no global warming and consequent sea level rise, this data may be useful in the case of storm surges taking place after cyclonic storms and rare tsunami, affecting this section of the Indian coast, the former usually in the months of October and November.

A detailed geomorphic map of Visakhapatnam city and its environs, between the east-west extending hill ranges of Kailasa in the north and Yerrada in the south was prepared using aerial photographs and field checks. Apart from the many landforms in the plains and the rolling topography within them, the notable ones, close to the hill ranges in the piedmont zone are the alluvial fans and colluvial deposits (Fig.9; Prudhvi Raju and Vaidyanadhan, 1978a). VUDA – Visakhapatnam Urban

Fig. 9: Geomorphological Map of Vizag Andhra Pradesh

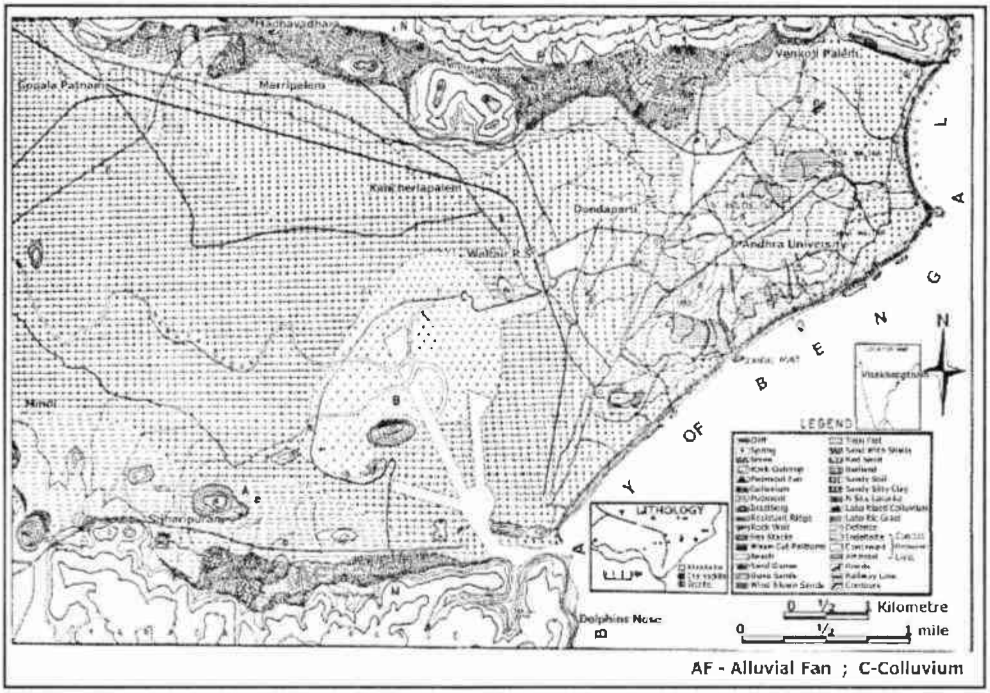
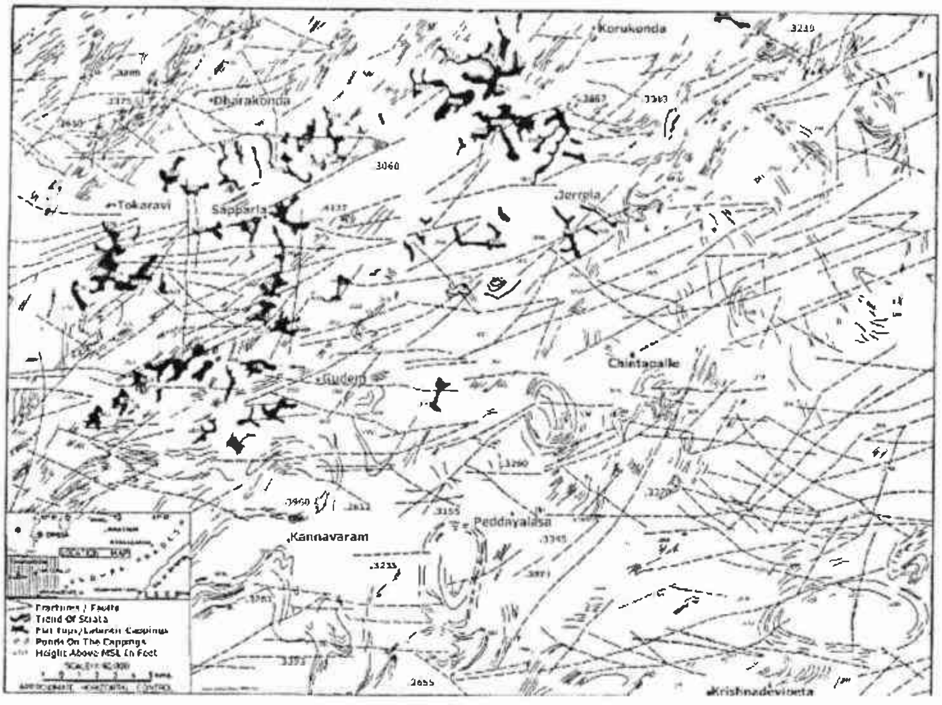


Fig. 10: Structure of part of Eastern Ghats in Chintapalle Area Vizag Distric, Andhra Pradesh



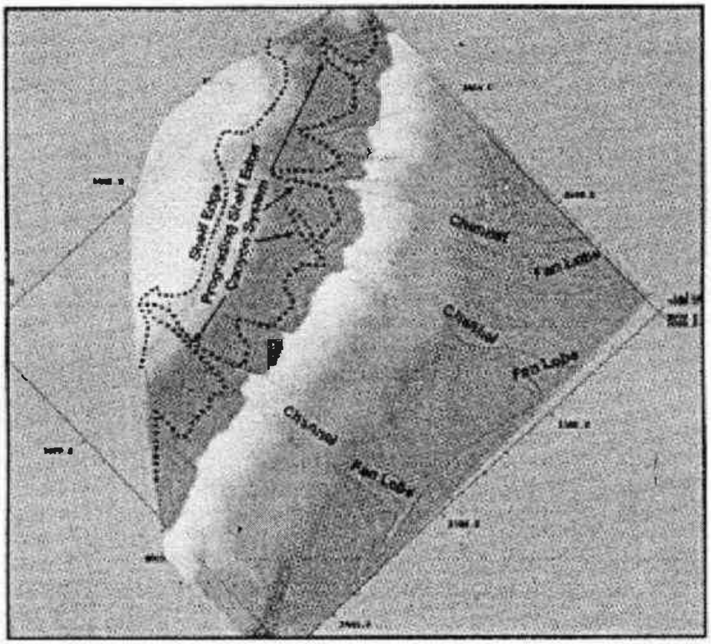
Development Authority – in order to provide better residences for the slum dwellers in different parts of the city, built a series of one room/2 room tenements on the southern slope of Kailasa range at 2 to 3 levels, taking the necessary construction material from the alluvial fans and colluvium along the foothill. This well-meant action resulted in the lowering of water table in the wells in the plain adjoining the foothill, as a substantial part of alluvial fans and colluvium were holding all the rain water directly precipitating over them and also flowing into them from the numerous consequent streams from above earlier. Now most of these deposits have been excavated. A lack of knowledge of the potential of these landforms has resulted in this unfortunate result. Of course, later some other sites have been suggested for the settlement of the slum dwellers. It was an avoidable folly.

An area of about 1200 sq. km in the mountainous part of Sarada River basin in Visakhapatnam district of Andhra Pradesh was mapped and folds, faults, fractures, lineaments and lateritic cappings were inferred and recognized from a study of aerial photographs (Fig. 10; Prudhvi Raju and Vaidyanadhan, 1978b). It was found that some of the bauxite deposits were in the lateritic cappings. Apart from this, the factors controlling the formation and preservation of these deposits, on extensive exploration, were recognized to be (i) favourable lithology and (ii) optimum slope of the lateirtic cappings enabling leaching of silica and iron and consequent enrichment of alumina due to meteoric waters (Ramam and Vaidyanadhan, 1981). Geomorphic factors have played a substantial part in the enrichment of these residual deposits.

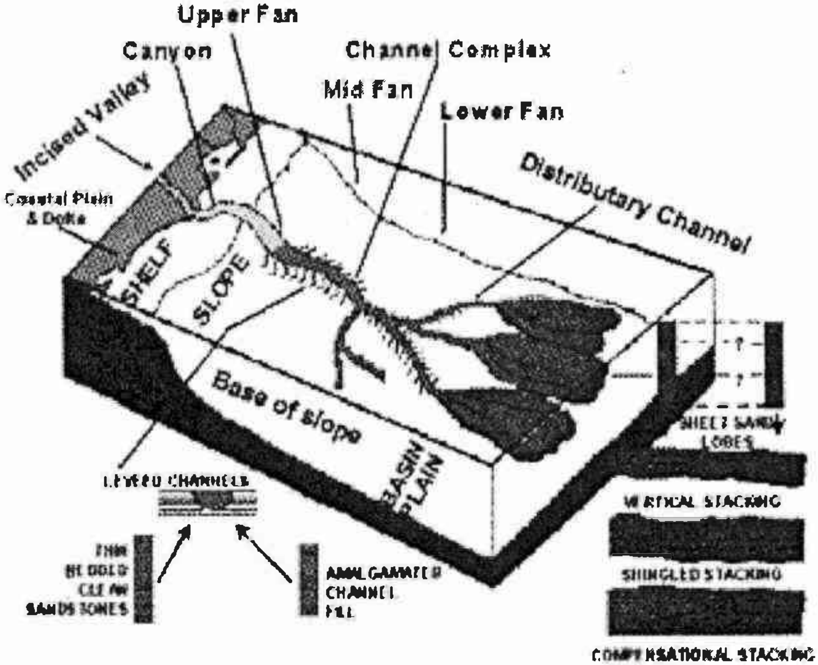
Using 3D seismic imaging, sub-aqueous morphology of an area in the Krishna-Godavari Basin was studied revealing major canyon systems and feeder channels for sediment transportation into deep water. The geological model indicates major elements of underwater topography including the distributary channels (Fig. 11; Bastia, 2004). The interesting part is the recognition of deep water sinuous channel forms in the Krishna-Godavari Basin, similar to those, for example, off Angola, west Africa (Fig. 12; Kolla et al. 2001). These have been recognized as possible repositories of oil and gas and some of these are being tapped for gas now, in the Krishna-Godavari Basin.

Attention has been drawn to the above studies in different parts of the world mainly to emphasize that it is the basic scientific information that is collected both from the field and use of sophisticated instruments, with a knowledge of the changing concepts, that ultimately facilitates application of geomorphology to various problems connected with the welfare of the society. I would like to conclude this address by referring to a BBC broadcast on the 14th December, 2009 on Nobel Minds, when a majority of the Nobel Laureates of the year 2009, seated around an oval table, were interviewed by a moderator. One specific question she asked almost all of them was, if they were conscious of the applications of their discoveries/finds, when they initiated their studies in their respective fields – physics, chemistry, medicine, physiology, economics etc. Almost all of them said that they were essentially driven by a desire to explore the basic nature of the problem – in other words, pursuit of basic science, and that if they were ultimately useful, through application of appropriate

Fig. 11: Subaqueous Morphology 3D Seismic Imaging 2004

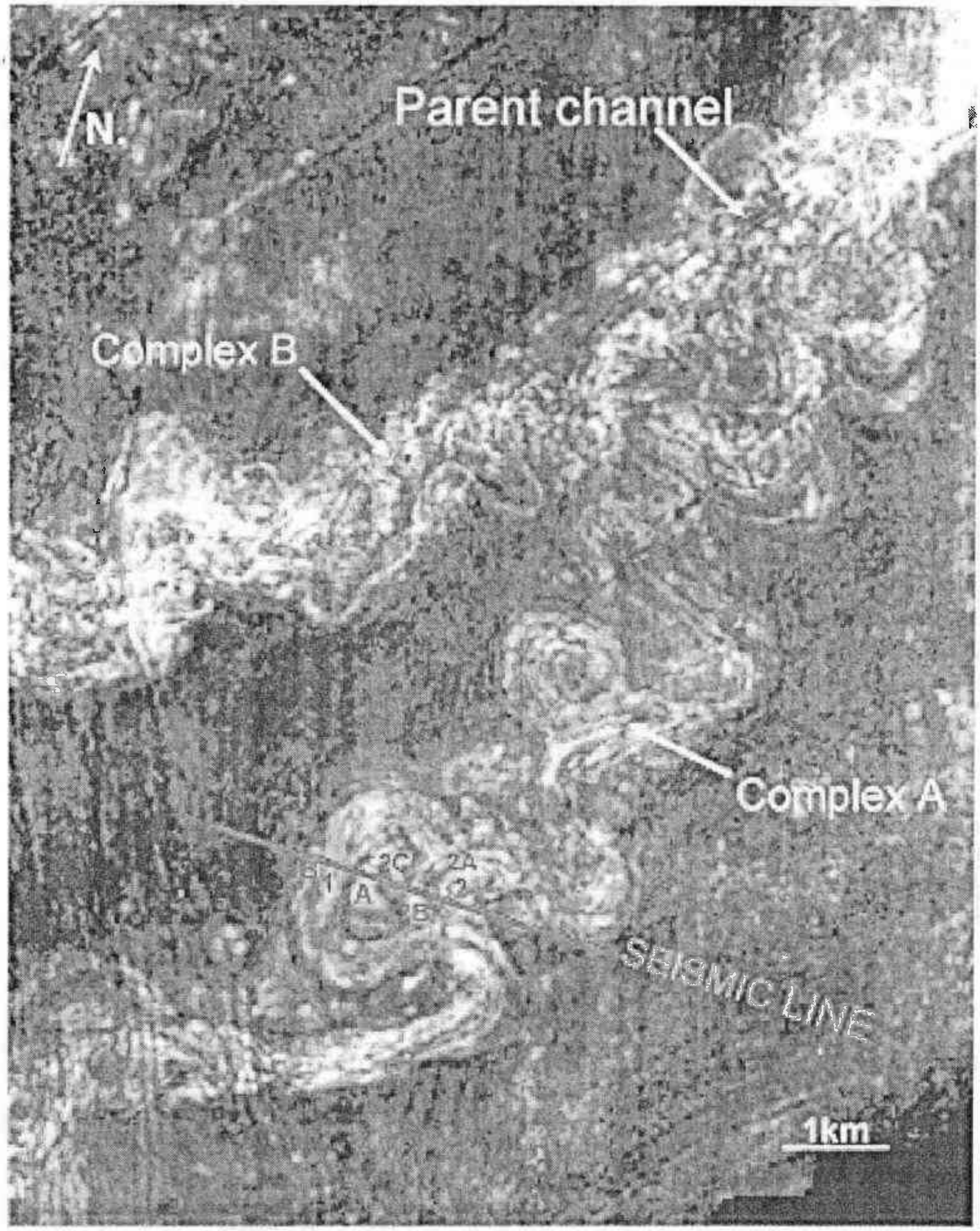


Illuminated view of the seabed showing major canyon systems and feeder channels responsible for the sediment transportation into deep water, Krishna Godavari Basin



Geological model exhibiting the facies distribution and reservoir architecture of deep-water depositional system, Krishna Godavari Basin offshore (channel-levee-fan complex)

Fig. 12: Deep Water sinouse Channel forms 3D Seismic Imaging - below ~ 2000-3000 m from sea level



Complex sinuous-channel systems. Two sinuous complexes-complex A and complex B - both originating from a single parent channel, are shown. The parent channel first took the course of complex A and then avulsed to complex B. features that resemble cutoffs are present in complex A. The sinuous loop consists of crescent-shaped high-amplitude seismic facies interpreted to be migratory channel course. (Kolla *et. al.*, 2001) technology to human kind in some form or other, it would be most welcome and they would be very happy about it. It is therefore my final appeal to the students and research scholars of sciences in general and earth sciences in particular to concentrate on collection of basic data every time, which will definitely in the short or long term lead to fruitful results.

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