Tertiary Fossil Forests in the Arctic

The term "fossil forest" refers to groups or clusters of more-or-less upright stumps of trees consisting of dried-out original wood or preserved as petrified wood. Fossil forests have been described from the Carboniferous of Nova Scotia, the Triassic of Arizona, the Jurassic of the U.K., the Cretaceous of Antarctica, the Cenozoic of Wyoming and elsewhere. However, none of these match those of Cenozoic age in the Canadian Arctic, for numbers of stumps in any one location, or for the exquisite preservation that keeps intact the finest details of the original cell structure and the qualities and composition of the forest litter and soil (see cover photo).

Figure 1: A stump 2.5 m high in Eureka Sound Group sands and shales on Ellesmere Island. Erosion has removed this stump from its surroundings since this picture was taken in 1955.

Cenozoic fossil forests have been known in the Arctic for more than 100 years. Indeed the first publication was in 1886 as an appendix to the records of the Adolphus W. Greely expedition. This refers to Brainard's "Petrified Forest," situated near Cape Baird on Ellesmere Island and discovered and described by Sergeant D.L. Brainard. Few details were recorded until 1955 when, as a part of the Geological Survey of Canada's Operation Franklin, the present author mapped and described the geology of the area 20 km east of Eureka Weather Station, on Ellesmere Island, where approximately 100 low, upright stumps are situated. The importance was then realized of the excellent preservation of the wood, and the existence of the remains of early Tertiary forest fires and of forest floor litter. The GSC has subsequently sponsored a succession of studies of the tectonics, stratigraphy, paleontology and palynology, as well as the economic implications of the presence of coal.

Some of the other organizations involved have been the Universities of Calgary, British Columbia, Saskatchewan and Toronto. Various studies have been carried out over the past 10 years by scientists from the Carnegie Museum of Natural History in Pittsburgh and Yale University's Peabody Museum of Natural History. In 1985, the writer brought Dr. Sidney Ash (Webber State College, Utah), a specialist on the Arizona petrified forests, to observe the broad aspects of

the Arctic occurrences. He encouraged Dr. Jane Francis of the University of Adelaide (Australia) to visit these localities and work on the wood, amber, soils, petrification, flora, fauna, fossil burns - in short anything likely to yield clues about the paleoclimatology.

Four fossil forests have now been found at widely separated localities on Ellesmere Island and one on Axel Heiberg Island. They occur at several stratigraphic levels within the Eureka Sound Group, and all seem to be of Eocene or Paleocene age (40-65 million years). The predominant trees are dawn redwood - *Metasequoia* - whose modern representatives are native only to one isolated valley in China.

The fossil forests are best preserved where the Eureka Sound Group, a sandstone-shale sequence, is horizontal or nearly so. The bedding commonly provides benches on stream valley walls where stumps can be preserved. The tops of the hills and spurs also are flat and likely places for fields of stumps. The trunks are up to 1 m across, with stumps 1/2 m to rarely 1 m high. They grew in a dense forest with trees 5 m apart. There was a thick and varied underbrush that provided leaf litter, cones and branchlets; at many stratigraphic levels this is probably the A zone of well-developed podzols. Well-preserved growth rings indicate that some trees grew to be 1,000 years old. The trees are preserved as wood, fresh enough to burn, partly lignitic in places. Petrification by silica replacement is fairly common but nowhere has it been found to be dominant.

Amber is ubiquitous. It occurs as globules of yellow, honey-coloured resin ranging from a few mm to 5 cm. These are being examined for the possibility of being host to

Figure 2: *Metasequoia* logs on flat-lying Tertiary beds, Northern Axel Heiberg Island. Wooden tree trunks on right are 10-15 m long.

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fossil insects. The forest floor is a rich collecting ground for seeds, cones and leaves, and fossil fungi are also present. Vertebrate fossils (bones, teeth and other remains) of horses, rhinoceroses, tapirs, tortoises, alligators and even lemurs have been found in the Tertiary elsewhere in the Arctic. When understood, these fauna and flora will be invaluable in understanding better the paleoclimates of the Arctic.

At 80° North latitude, the climate today is severe polar, and with 4 1/2 months of continuous darkness and 4 1/2 months of continuous sunlight, it supports only a sparse flora and fauna. In contrast, the climate in the Eocene-Paleocene was clearly moist and warm, for there was a dense, lush vegetation. Evidently the whole world was warmer then. The vast amounts of CO₂ that may have been vented during the volcanism associated with active seafloor spreading in the late Mesozoic-early Tertiary, could have imposed a greenhouse effect that did not substantially dissipate until the Miocene. Alternatively, the paleolatitude may have been 35-40°, as the fossil record might suggest. If so the paleomagnetic data and their implications would need to be re-examined.

The dawn redwood, growing to heights of some 50 m, was presumably able to adapt to the long cycle of dark and light, if the first case is accepted. The question remains as to how the redwoods and associated flora adapted to these light conditions with the inevitable constraints on photosynthesis. Many questions concerning the evolution and adaptation of plants can also be raised.

There may also be an economic spin-off. GSC geologists have known for several years that resin and amber are source materials for oil and gas at lower levels of maturation than organic matter derived from algae. The Arctic forests may help to determine which plants produce the resin, how it is preserved and how it is transported, as well as its distribution in time and space. And there are suggestions from the vertebrate fossils that the Arctic may have played a major role in the evolution of organisms migrating across the poles from mid-latitudes during the Tertiary. There is clearly a wealth of data here and years of work ahead for vertebrate paleontologists and paleobotanists alike. □

N.J. McMillan
Calgary, Canada

Regional Himalayan Structure in Central India

The existence of broad gravity highs over the central part of India has long been recognized. In 1901 Col. Sir Sydney Burrard of the Survey of India had postulated a hidden high-density range in Central India on the basis of positive gravity anomalies. An alternative presented in 1977 by W.E.K. Warsi and P. Molnar (MIT, U.S.A.) argued the case for a kilometre-high lithospheric flexure. A new study by P.K. Agrawal, N.K. Thakur and J.G. Negi (Geophysical Research Letters, vol. 13, p. 491-494, May 1986) links doming of the Central Indian crust with the Himalayan range and with sea-floor spreading forces emerging from the Carlsberg ridge.

The recent study reviews a joint inversion of magnetic satellite and free air gravity data and "geo-relief" information that indicate the existence of a structural ridge that is about 1500 km long and 300 km wide with as much as 6 km of upwarping of the crust-mantle interface around Amarkantak, Madhya Pradesh. This crustal dome runs parallel to the Himalayan range in a NW-SE direction at a distance of 700-800 km from the India-Eurasia collision boundary. The structure is bounded by the Mahanadi-

Godavari rift valley in the east and the Aravallis in the west, and there is also a remarkable parallelism with the Carlsberg ridge to the south in the Arabian Sea.

The central Indian fold is regarded as the product of continent-continent collision of India with Eurasia about 40 million years ago. Present collision models assume that the Indian subcontinent was a rigid block that, on its northward journey of 9,000 km, indented a ductile Eurasian plate forming the Himalayan mountain system with a 2,000-km wide zone in the northern side. The new study clearly indicates, however, that the Indian block to the south of this collision zone also suffered folding and crustal shortening due to continuous convergence of the continents and the ongoing sea-floor spreading. The discovery has considerable importance for the understanding of collision tectonics, deep regional geology and the process of refolding the remanent mountain systems of the Vindhyan, Satpura and Maikal ranges of Central India. □

J.G. Negi
Hyderabad, India

INQUA's Commission on Loess

World-wide research on loess is correlated and encouraged by the INQUA Loess Commission. This has been particularly active in recent years, for loess studies are rapidly growing in popularity. The Commission was founded by Julius Fink at the 1961 Warsaw Congress of INQUA as a sub-commission mainly concerned with loess stratigraphy in Europe. This became a full commission in 1969, as interest increased and became broader. Dr. Fink commented on this in his presidential address at the Hungarian Loess Symposium in 1971:

"The widening of the Subcommission on Loess to form an independent commission of INQUA will allow inclusion of other loess-covered regions beyond the confines of Europe into the scope of our activities. In addition, the new organizational structure will allow more thorough discussion of the problem of applied research. In this connection a very real ulterior motive of this re-organization should be mentioned: if the INQUA

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Loess Commission is able to contribute to the solution of present-day tasks and objectives, it is entitled to expect financial support from institutions which are interested only in investigations with practical aims."

Loess stratigraphy is still a very important activity, but there is great interest in engineering problems - particularly subsidence and erosion. The most productive agricultural soils are loess soils whose value is being more fully appreciated as the increasing world population requires more and more food. Wind erosion remains a problem in loess soils, and there is a considerable research effort in this field. There are still many lithological and geomorphical problems associated with loess, and there is still room for discussion on the classic "loess problem" - how was it formed, where did it come from, and why is it where we find it?

Figure 1: Chinese geologists studying a loess-paleosol section. From "Loess in China," Shaanxi People's Art Publishing House, 1980.

There has been a startling and welcome recent growth in published material from China. The first evidence for multiple paleosols in the thick Chinese loess section (Fig. 1) was presented at the 1961 INQUA Congress in Poland. The importance of this observation was not appreciated at the time, but the Chinese sections are now seen as one of the major windows to the Quaternary period. In 1985 the first research institute devoted to the study of loess was opened at Xian - a truly significant event in the appreciation of loess. A major civil engineering program is now underway to move water out of the Yangtse Valley in the central part of China up to the dry loess lands of the north (Fig. 2). When this is completed and the loess regions are restored to their old productivity, a major contribution to world food production will have been made. Joint programs are being

Figure 2: Loess landscape near Ansai, Shaanxi Province. From "Rock Desert, Gravel Desert, Sand Desert, Loess," Shaanxi People's Art Publishing House, 1983.

developed to enable investigators from all countries to share in the riches of the Chinese loess. A link has already been established between the Xian Institute and the University of Leicester (U.K.) to facilitate joint projects and the exchange of samples and personnel.

One of the major long-term aims of the Commission has been to produce a map of European loess deposits. This will supercede the map produced in the early 1930s by Rudolph Grahmann in Leipzig, which has been the standard map of European loess distribution for 50 years. However, this project, set in motion by Fink, is proving difficult to complete, for there are many difficulties in fitting data across national boundaries. The production of the map is being directed by Gunter Haase of the D.D.R. Academy of Sciences who works, very fittingly, from Leipzig. The idea of producing a loess map of the world has been discussed, but no specific project has yet been initiated.

On a global scale, all large loess deposits save one are being actively investigated by members and associates of the Loess Commission. The exception is the large South American deposit in the region of southern Argentina and Uruguay. Little more is known about this deposit now than when Charles Darwin galloped across it.

The idea that loess could be a climatic "register" appears to have been first proposed by John Hardcastle at Timaru in New Zealand in 1891. Studies in China and in Europe have now convincingly demonstrated that the loess provides one of the best indicators of the variation of climate over the past 2 million years. The long sections in China span all of the Pleistocene and display a remarkable series of well-marked paleosols (see Fig. 1 and review by Liu et al., *Episodes*, vol. 8, March 1985, p. 21-28).

The most promising areas for stratigraphic research appear to be Northern China and Central Asia. Data on the Central Asian sections are emerging more slowly, but there can be no doubt that the thick loess deposits of some southern Soviet republics will add greatly to our stratigraphic knowledge.

As appreciation of the information-filled loess sections has grown, so techniques have been developed to exploit them. Thermoluminescence dating appears to be particularly well

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suited to the dating of loess material, and the matching of techniques and materials has led to great progress in the dating field.

A new working group on loess geotechnology is being organized by N.I. Kriger from Moscow. A study of geotechnical loess work in Russian from 1978-1982 has just been completed by the working group and may be published in time for the 1987 INQUA Congress. The major geotechnical problem in the Soviet Union is probably that of subsidence - but in China it is probably landslides. The landslide danger is so acute in the loess regions of northern China that a new institute has been set up to study them and to combat the problem. This is the Geological Hazards Research Centre of Gansu, based at Lanzhou.

Thanks to the generous assistance of government agencies in New Zealand and Canada, the Loess Commission has managed to maintain a modest but continuous publishing program for the last nine years. A newsletter, *Loess Letter* (LL), is published twice a year, and supplements are produced when the occasion demands and funds allow. With the aid of a grant from the Natural Sciences and Engineering Research Council of Canada, twelve special supplements (nos. 8-19) have been produced for the 1987 INQUA Congress.

One of the aims of *Loess Letter* is to improve communication between loess workers who live in different countries, use different languages and specialize in different disciplines. The five major languages used by loess

researchers appear to be Russian, Chinese, French, German and English. Until about 1977 most of the Commission's business was transacted in German, but since then English has essentially taken over. The one really significant linguistic barrier that still exists is the one that separates the Russian and the English speakers. The Russian loess literature has certainly not received the notice it has deserved from English speaking researchers. In the Ottawa supplements LL makes a small attempt to bridge the gap by offering some Russian literature both in translation and in the original language. One example is a translation into English of the 1952 *Novyi Mir* paper by V.A. Obruchev, probably the first comprehensive statement in English of the views on loess formation of this very important loess investigator.

Copies of LL can be obtained from the current publication office: Department of Geography, Leicester University, Leicester LE1 7RH, England. Further information about the Commission may be obtained from its President, M. Peesi, Geographical Research Institute, Hungarian Academy of Sciences, H 1112 Budapest, Budaorsi ut. 43-45, Hungary.

There is no doubt that loess is one of mankind's great resources - we should treasure and protect it - and where it has been damaged we should restore it. Loess is too valuable to neglect. □

Ian Smalley
Leicester, England

Local Monitoring of Soviet and American Nuclear Tests

In an extraordinary recent development, the U.S.S.R. has made a one-year agreement with a non-governmental American organization, the Natural Resources Defense Council (NRDC), to monitor the main Soviet nuclear test site, for the first time on Soviet soil. The NRDC team, led by American seismologists J. Berger and J. Brune of the

Institute of Geophysics and Planetary Physics (University of California at San Diego), installed their first seismic instruments in early July near Karkaralinsk, a small town some 150 km southwest of the main test site near Semipalatinsk in easternmost Kazakhstan. To form a simple triangulation net, two others have since been set-up, also in cooperation with the Soviet Academy of Sciences, at other locations within a 200-km radius of the main test site.

One goal is to determine the transmission properties and background noise levels of this part of the Kazakh Uplands. This will help to gauge the feasibility of monitoring any future test ban treaty. Efforts are also being made to identify all seismic activity recorded and to distinguish between earthquakes, industrial explosions and mining operations while the current Soviet moratorium on nuclear tests is in force. Indeed, many explosions from mines in the region have already been recorded, as well as earthquakes originating to the south and east in the active tectonic region bordering the Soviet Union. The first seismometers were set up on the surface, but others will be installed at the bottom of holes about 100 m deep now being drilled into solid rock.

The plan is for Soviet seismologists to visit the Nevada test site area of the U.S.A. for reciprocal observations in late 1986. NRDC is an environmental protection group concerned with a wide range of issues from air and water pollution to energy and land conservation. The Council places priority on responding to the hazards posed by nuclear energy and weapons. □

Figure 1: Installing a seismometer in the full glare of the media - Karkaralinsk, Kazakh S.S.R. Photo courtesy of T. Cochran, NRDC, Washington D.C.

New Map of Lithospheric Dynamics of China

The Geological Publishing House in Beijing will publish in 1987 a new Lithospheric Dynamics Map of China and Adjacent Seas, together with an explanatory memoir. These are products of a three-year study, and highlight the progress by Chinese earth scientists over the past decade towards an understanding of the nature and dynamics of the lithosphere beneath China. The focus is on interplate phenomena and on explaining them in terms of fundamental plate tectonic processes.

The map portrays, on a scale of 1:4,000,000, active plate, sub-plate and block boundaries and their relative motion vectors, crustal and lithospheric thickness, Pn velocity, and earthquake epicenters, giving the date, magnitude, focal depth and focal mechanism where known. Also illustrated are gravity and aeromagnetic anomalies, stress determinations, major active faults and their rates of relative displacement, both vertical and horizontal, and

Cenozoic basins, active folds, magmatism and volcanic centers. The base map shows national boundaries, bathymetry, topography, and other selected geographic data.

The map gives an overview of geological and geophysical processes that are presently active or have been active in the recent geological past. It provides a background for further research on contemporary lithospheric dynamics and serves as a regional framework for extrapolating those active processes into the geological past and the future.

This is Publication No. 0126 of the International Lithosphere Program and is being published with its accompanying memoir by the Geological Publishing House, Xi-Si, Beijing, China. The tentative price is US \$40. □

Ma Xinyuan
Beijing, China

Planning for a Global Sedimentary Geology Program

A combination of favourable circumstances is encouraging the initiation of a new international effort of global sedimentary geology. The global temper of the times that is evident in communications, transportation, trade and politics is also seen in the earth sciences in plate tectonics, paleoceanography, paleoclimatology and seismology. Sedimentary geology, the study of unconsolidated sediments and their fossilized counterparts, is poised to join in this expanded view of the earth.

Sediments and sedimentary rocks are the archives of much of the earth's history and the evolution of life. These deposits contain most of humankind's resources of fuels, water, metallic ores and building material. Ancient sedimentary rocks are a kind of cardiogram of the pulse of earth movements: they contain the only record of some three billion years of changes in the hydrosphere, biosphere and atmosphere.

A series of remarkable advances in sedimentary geology during the past four decades provide a foundation of new approaches and new concepts for a major expansion to global-scale questions. Among these innovations are refined time telling, conceptual models of depositional patterns, circulation of the oceans and atmosphere, plate tectonics, isotope geochemistry, seismic stratigraphy and remote sensing.

To take advantage of these favorable circumstances for expanding sedimentary geology, a Global Sedimentary Geology Program (GSGP - formerly referred to as an International Decade of GSG) is needed to provide the focus, the opportunities, and the impetus for global-scale research and

thinking. For this new program, three major themes for research are identified: Global Rhythms and Events; The Sedimentary Record of Global Evolution; and The Global Analysis of Sedimentary Lithofacies. GSGP would be necessarily international and would therefore offer a special opportunity for training scientists and the exchange of scientific and technical experience. The research projects would provide for collaboration and internship for younger scientists, short courses and workshops, and visiting scientists can transfer experience from the developed nations to the less developed ones.

An international parent organization is needed to implement this new program; its first action should be to appoint an Organizing Committee that can define the objectives, describe the administrative structure and set a plan of action for initiating the Global Sedimentary Geology Program. □

from report on an International Workshop on GSGP
Miami, U.S.A., June 19 - 22, 1986,
Courtesy of R.N. Ginsburg, Miami

IAVCEI Statement on High-Risk Volcanoes

The eruption of Nevado del Ruiz on November 13, 1985, caused the death of 25,000 people. The potential for tragedies of similar or greater dimensions exists at many other volcanoes, especially in developing countries. The International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI), on the occasion of the International Volcanological Congress in New Zealand (February 1986), strongly urges that programs to reduce the risk of major volcanic catastrophes be initiated and given lasting support.

An inventory of especially dangerous volcanoes was recently prepared by IAVCEI and Unesco. About 100 high-risk volcanoes were identified; most of these lie around the Pacific Ocean Basin in Third World countries. IAVCEI has also recently commissioned a task force that will develop a broadly defined strategy to mitigate the hazards of high-risk volcanoes.

Effective programs that would lay a foundation for long-term mitigation of volcanic hazards must include the following:

- Training of scientists from developing countries having such volcanoes. This is paramount in order to bring about long-term self sufficiency in volcano monitoring with such countries.
- Studies of previous eruptive behaviour; preparation of hazard-zonation maps, hazard information and training for people living near high-risk volcanoes; and advance interactions with responsible civil authorities.
- intensified monitoring of dangerous volcanoes showing current signs of unrest; and long-term base-line monitoring studies of other high-risk volcanoes.

We ask the research and aid agencies of the Developed Countries to pool their financial resources to initiate and maintain the proposed program on high-risk volcanoes. The amount of money needed is small compared to many scientific and aid programs, but long-term stable funding is essential. This program is needed now; we cannot wait for another disaster like that at Nevado del Ruiz. □

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