greatly benefits Canadians, so will Norwegians and Canadians benefit by meeting in Norway.

Persons interested in either the course in Norway, or the field course in glacial hydrology expected to be offered in 1976 or 1977 again in Canada (probably at a glacier in the coast mountains in B.C.) may obtain further information by writing to the Department of Geography, Carleton University.

Acknowledgements
This article is partly based on contributions, oral and written, from persons taking part in the course.

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Correction
In the last issue, the report on the Conference on Grenville Geology and Plate Tectonics was attributed to only one author, A. J. Baer. The list of authors should have included the other members of the Canadian Geodynamics Committee, R. F. Emslie, E. Irving and J. G. Tanner.

Geodynamics of Iceland and the North Atlantic Area

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Iceland, the ancestral home of the first explorers of North America, has become a scientific playground and a key study area for geoscientists concerned with the development and understanding of the Plate Tectonic Hypothesis (PTH). This anomalous volcanic island is located astride the Mid-Atlantic Ridge and represents the largest 'outcrop' of the Mid-Ocean Ridge system. With relative ease, PTH can be tested in Iceland, and under this stimulus a wealth of new observational evidence has been accumulated there in recent years.

Under the auspices of a NATO Advance Study Institute, some 80 scientists from 12 countries assembled recently in Reykjavik to examine this new evidence. PTH was put to test and found not wanting; the new observations have suggested, however, refinements to the hypothesis and new experiments to expand further the framework for global geology. The group that came together in Reykjavik consisted mostly of those already converted to the new hypothesis. When the proceedings of the Institute are published, all the critics of the PTH will not be silenced. A strong contingent of Soviet scientists who originally suggested the format for the meeting and who were going to present the opposing points of view did not show up and thus a big gap was left in the programme.

The oldest rocks in Iceland are 16 million years old. The rocks are younger towards the centre of the island and the most recent ones are located within two neovolcanic zones, splitting the land from southwest to northeast, roughly paralleling the trend of the Mid-Atlantic Ridge in this area. The rocks are of basaltic composition with only a small fraction with acidic affinities. The area is an active geological laboratory. It has been estimated that in the last ten thousand years some 480 km^3 of eruptives have been produced in 250 volcanic eruptions. The heat flow is intensified and the heat production has been estimated at 15,000 Mw/sec. (Part of this heat is utilized by the Reykjavik District Heating System to heat 80 per cent of the homes and provide hot water. In 1970 the total sales of hot water amounted to an equivalent of 1170 million kwhrs of electrical energy. Without the hot water system, at the present day prices, it would cost some $10 million a year in foreign currency to pay for imported fuel oil – an economic burden which the country could not afford.) The area is also an active seismic zone and provides an unparalleled opportunity to study the swarms of microearthquakes associated with the rifting of the earth's crustal layers.

Over forty years ago it was recognized that Iceland is 'anomalous' and it is still so classified, primarily because all other oceanic islands of comparable size represent continental fragments. The first experiments to obtain direct evidence for Wegener's continential drift theory were attempted by German scientists in 1938 and the Institute heard from one of the original investigators, Professor A. Schleusener, University of Hanover, about the continuation of that work. Using precise geodetic surveying and repeated gravity measurements, the aim is to measure the actual displacement and widening of Iceland (expected to be of the order of two cm per year). The most recent repeat measurements give measurable displacements but the movements are not systematic and not always in the expected direction. Because of a possible erratic movement of bench marks and limited precision of survey instruments, the measurements will be required over a period of some tens of years in order to reach any conclusions.

These measurements were carried out across the physiographic expression of the central rift which corresponds to the Median Valley of the Mid-Ocean Ridge system. The description of the shape and origin of this rift is not yet complete. S. Thorarinsson, University of Iceland, showed a number of slides illustrating the geomorphology and a wealth of volcanic shapes on Iceland. The ocean floor rift cannot be that easily illustrated and our conceptualization is based on indirect evidence based on echo sounding techniques. A. S. Laughton of the Institute of Ocean Sciences, England, presented a unique sonograph of an area of the Mid-Atlantic Ridge Median Valley obtained with a side looking sonar with a visual range of 12 km. Compilation of these sonographs showed an area of about 100 x 100 km with the structural texture of sub-parallel ridges offset by three large fractures and divided into large fault blocks. Obviously a great deal more 'sonography' of mid-ocean ridges is desirable to increase our appreciation of the geomorphological expression and tectonic processes at the accretion edges of the lithospheric plates.

T. J. G. Francis, Institute of Geological Sciences, London, offered an ingenious and plausible explanation for the Median Valley. He had studied in detail the collapse of a caldera on Isle Fernandina, Galapagos, in 1968, which he termed "the most spectacular geological event on the surface of the earth in our lifetime". Caldera floor, 7 km² in area, dropped 300 m, causing 295 earthquakes occurring in a seismic swarm over a period of 12 days. By comparing the characteristics of these earthquakes with those observed with ocean bottom seismometers near the median valley, Francis concluded that the median valley could be formed by a process of caldera collapse.

Seismic evidence for the structure of oceanic layers and for the composition of the layer 3 was reviewed by N. I. Christensen of the University of Washington, Seattle, who brought up to date Raitt's 1963 classification of oceanic rock. In addition to confirming the gross structure and velocity distribution, he was particularly concerned with methods for differentiating between continental and oceanic rocks of the same seismic velocity of 6.0 to 6.5 km/sec. He believes that a distinction between two types of rocks can be made on the basis of the Poisson's ratio but more measurements of shear wave velocity in oceanic rocks is required.

After considering this indirect evidence for the geological composition of the oceanic rocks, the Institute studied the rocks as exposed in Iceland.

Because of a total lack of mineral resources, the geology of Iceland was not well known until its anomalous situation attracted the attention of the protagonists of the continental drift. Through careful field work over the past twenty years, G. P. L. Walker of the Royal School of Mines, London, has done much to advance the understanding of the tectonic setting at the crest of a mid-ocean ridge. In 1963 he published (together with Bodvarsson) a classic paper proposing the ridge crest growth by a dyke injection mechanism. At the Institute he proposed that the sheet complex in S. E. Iceland could be the top of layer 3. He explained that percolation of surface water through the top 100 to 200 metres of porous and fractured volcanic rock represents an effective barrier which it is difficult to unclog by rising magma. The sheet complexes arise when high density, low viscosity magma has a volumetric rate not high enough to penetrate the surface barrier. An important inference for the ocean floor processes is that the level of magmatism cannot be related to surface activity. This may explain the general absence of eruptive processes on the sea floor along the mid-ocean ridge system. A better indication of magmatism at the accretion edges of plates is the surface deformation and the heat flow.

Additional information on layered complexes came from Dalhousie University programme of deep drilling at 45°N on the Mid-Atlantic Ridge, on Bermuda and Azores islands and on leg 37 of the Deep Sea Drilling Project using the drill ship *Glomar Challenger.* In Bermuda, titanium-rich basic intrusives represented 36 per cent of the core recovered. In the Azores where the drill penetrated mostly subaerial and shallow submarine lavas, no intrusives were noticed. The Azores are younger than Bermuda and appear to be sinking at a higher rate than that expected from the cooling of an underlying magma chamber.

The origin of magmatism and deep-seated driving mechanism for the motion of tectonic plates is the major unknown at the present time. A convective flow upwards from the lower mantle appears to be a plusible mechanism and a number of models have been developed to describe mantle plumes and hot spots. Such a mantle plume might exist under Iceland and may be responsible for a large discharge of lava there. Geochemical evidence seems to be of key importance and a number of lively sessions of the Institute debated a single or differentiated mantle as a source for lava, the strontium and oxygene isotope ratio, phase transformations, enrichment of incompatible elements and other topics. G. E. Sigvoldason of the Nordic Volcanological Institute, Reykjavik, on the basis of study of chlorine in basalts from the neovolcanic zones in Iceland concluded that basalts produced in a mantle plume centre, such as Iceland, are likely to be highly enriched in volatiles, hence such centres can be called 'chimneys' for degassing of the Earth. From the comparative analysis of dredged rock from the Mid-Atlantic Ridge and Iceland, J-G. Shilling, University of Rhode Island, has shown that there is an enrichment of rare earth elements as one approaches Iceland. From this and other evidence, he postulated that plume basalts and mantle lava do not originate from the same source. His further conclusion was that plume flux does not control the rate of spreading. Blobs (impulse flow) are declining under Iceland at present whereas the spreading rate is increasing, hence Iceland may split into two.

Indirect evidence for mantle plumes was further discussed by M. Langseth of Lamont-Doherty Geological Observatory, New York, on the basis of 62 heat flow measurements in the Norwegian Sea. He showed that Iceland is in the centre of a broad area of high heat flow. He postulated that the thin lithosphere and anomalously high temperature at its base are the result of a spreading rate which is too low for the supply of heat to be dissipated. The conclusion is that something is constraining the plates from moving apart freely. Since Iceland is considered anomalous, this constrained motion does not occur everywhere and the inference could be that different plates show different degrees of rigidity through time. Further evidence on this key problem was provided by Laughton, who showed bending and distortion at the European plate edge along the Azores-Gibraltar fracture zone; and by B. Voigth, Pennsylvania State University, who reviewed borehole measurements of ambient stress in rocks. Voigth showed how the advances in the technique of in situ stress measurements have improved and advocated more deep drilling on land. In addition to providing information on ancient continental collisions and possible identification of seismic layer 3 rocks, stress measurements in deep bore holes might give information regarding rigidity of lithospheric plates.

In order to test the original formulation of the PTH, it was necessary to assume that lithospheric plates were rigid and not deformable during continental drift movements. Many land geologists familiar with faulting and folding within the continental land mass could not accept this assumption and frequently rejected the whole PTH. The assumption was necessary in the initial development of PTH since, without it, purely kinematic determination of plate motions based on matching magnetic patterns and orientation of fracture zones could not be worked out. As the additional evidence acumulates and our understanding of PTH increases, the plate rigidity assumption will be relaxed.

Geophysical evidence for intra-plate deformations will come from regional heat flow measurements, from averaged gravity anomaly interpretations, from higher resolution in interpretations of seismic records, and from measurements of in situ stress in deep bore holes on land as well as at sea.

Direct measurements of displacements between lithospheric plates are now possible and should be undertaken not only at the edges of the plates (as in Iceland or across the Gulf of California) but also between stable shield areas using long baseline interferometry and laser signal bounce from the reflectors on the moon. In addition, equipment should be developed for emplacement on the ocean floor for direct measurements of displacement on the mid-ocean ridges. These experiments are going to be slow and will require persistence over several decades, but the scientific rewards will be great.

Finally, work in experimental petrology and geochemistry is now producing a wealth of new data which is not yet fitting into a simple framework. When these data are sorted out there will undoubtedly be a great leap forward in our understanding of the internal constitution of the Earth. This understanding in turn will lead to a better model of the Earth as a thermodynamic engine.

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17th Conference on Great Lakes Research

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Summary
Limnogeology continues to account for a significant part of the research reported in the annual Conferences on Great Lakes Research. At this year's meeting the emphasis was on stratigraphic studies of post-glacial sediments, surface sediment geochemistry and shore processes. This is a reflection of current practical concerns with sediment loading, "cultural enrichment" of sediments and accelerated shore erosion.

Introduction
The Great Lakes Conference is an annual conference dealing with all aspects of Great Lakes' research including geology and geophysics. The conference is associated with the International Association for Great Lakes Research which provides the direction and continuity but is hosted by individual universities or research centres in the Great Lakes area. This year it was held at McMaster University in Hamilton, Ontario during August 12-14 and was co-sponsored by McMaster and the Canada Centre for Inland Waters (CCIW) in nearby Burlington.

Geologically-oriented papers generally make up 15 to 20 per cent of the technical sessions. This year there were 28 papers presented in three sessions titled Geology-Isotopes in Sediments, Great Lakes Geochemistry, and Shore Erosion/Beaches and chaired respectively by Drs. Tony Kemp and