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Report on the second meeting of the Canadian Tectonics Group held on 23–24 October 1982 at Gravenhurst, near Toronto

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The second annual meeting of the Canadian Tectonics Group was organized by P.-Y. F. Robin and W. M. Schwerdtner of the University of Toronto, and held on 23–24 October, 1982. Like the first annual meeting in 1981, this one was kept as small as possible and all participants were required to read a paper or present a poster. A general session (17 papers) was held on the first day, and the second morning was devoted to structures in the Grenville Province of the Canadian Shield (7 papers). A total of 10 posters were presented in two time slots specifically reserved for this purpose. The afternoon of 24 October was used for a short field trip, led by W. M. Schwerdtner to illustrate the topic 'Fragmentation of Grenville gneisses in the ductile realm'.

The general session on 23 October was held in two parts. The first part (morning) was devoted to macrostructure and the second part (afternoon) was given over to microstructures. Macrostructural topics fell into the scope of plate tectonics, geostatistics, strain analysis, etc. Topics of posters also reflected the breadth of structural research in Canada.

The Canadian Tectonics Group plans to retain the format of the first two meetings in the future. The 1983 meeting will be organized by structural geologists in Edmonton, Alberta.

ABSTRACTS OF PAPERS PRESENTED

Diapirism of the Morin anorthosite; evidence from the petrofabrics of quartz c*-axes of surrounding granulites.* C. Barraud and J. Martignole, Département de Géologie, Université de Montréal, C.P. 6128, Montréal, P.Q. Canada H3C 3J7.

Petrofabric analysis of quartz *c*-axes from supracrustal rocks in contact with the Morin anorthosite (Grenville Province) was used to establish the relationship between quartz microfabric and diapirism. Isotropic quartz fabric mainly occurs southwest of the anorthosite dome, in mesoperthite-bearing leucogranulites, close to the granite minimum and in granoblastic annealed granulites. Conversely, non-isotropic quartz fabric is interpreted as the result of stresses acting during or after the last crystallization or recrystallization. This fabric is characterized by a point maximum or a small girdle. The orientation of quartz *c*-axes is not related to the mesoscopic foliation, but tends to be oriented perpendicular to the contact of the Morin anorthosite. The absence of relationship between mesoscopic fabric and quartz axes suggests that the latter is due to a late strain. Inasmuch as quartz *c*-axes tend to be oriented according to the last strain increments, the radial strain pattern around the Morin anorthosite would be compatible with the ascent and spreading of the mass as a late event not followed by regional deformation and metamorphism. The presence of fairly large tracts of granulites with an almost isotropic quartz fabric shows that crystallization from anatectic melts or metamorphic recrystallization locally outlasted dynamic crystallization.

Origin and deformation of the North Mokka anticline, a typical structure in the Western Eureka Sound fold belt, Axel Heiberg Island, Canadian Arctic. Jean van Berkel, Department of Geology, University of Toronto, Toronto, Canada M5S 1A1.

The North Mokka anticline on central eastern Axel Heiberg Island is one of numerous doubly-plunging anticlines in the Eureka Sound fold belt. Its southern nose is cut by a large second-order evaporite diapir, the Mokka Fiord diapir (Schwerdtner & Clark 1967). Structural evidence suggests that the anticline is not a buckle fold due to E–W compression (Thorsteinsson 1974) but a first-order diapiric ridge due to halokinesis (Trusheim 1960).

The anticline comprises at least three coalescent domes that form a N–S chain. The middle dome has a teardrop shape with an apex to the south, and contains a small second-order evaporite diapir in its core.

A NNW–SSE to N–S trending fault with a steep westerly dip cuts the southern and middle domes and forms the southeastern contact of the Mokka Fiord diapir. It truncates the internal structure of the small diapir in the middle dome. The fault is regarded as a minor branch of the Stolz thrust zone, which trends NW–SE about 10 km southwest of the North Mokka anticline.

Northeast and northwest trends in the Grenville Province—expressions of propagating shear-zones? N. G. Culshaw, Department of Geology, University of Ottawa, Ottawa, Ontario, Canada K1N 6N5.

At the margins of ductile shear zones in the western Grenville Province, a fairly common feature is the juxtaposition of an unfolded foliation, bearing a down-dip stretching lineation, with an over- or underlying zone of folding. Lineation in the unfolded foliation, often plunging moderately to the southeast, is commonly parallel to the fold axes. This feature may be present locally or on a regional scale. In the latter case large areas of NW-trending foliations may be truncated by the SE-dipping foliation of the shear zone, both areas bearing a moderately SE-plunging lineation.

Ramsay & Allison (1979) have suggested that when a shear system is constrained in the Z direction, contraction may occur below the leading edge of a propagating ductile shear. If a passive layering, originally parallel to the shear plane, is introduced into their model, folds with their axes parallel to the stretching lineation may form in the zones of contraction. Consequently, when the shear plane dips moderately to the southeast parallel to the lineation, NW and NE trends may be formed simultaneously. Also the model predicts that locally, as the shear zone propagates, folds with NW-striking axial surfaces will be overprinted by those with NE-striking axial surfaces.

Large-scale structural patterns in the central gneiss belt, Grenville Province of Ontario. A. Davidson, Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario, Canada K1A 0E8.

Curvilinear zones of layered gneiss in the central gneiss belt, Ontario Grenville Province, are moderately to gently dipping, more than 1 km thick, and continuous for scores of kilometres. On the map they surround, wholly or partly, domains with internally complex, smaller scale structure and distinctive lithologies and metamorphism. Regionally, NE-trending zones truncate structure to the northwest, NW-trending zones truncate underlying structure. Conventional concepts, namely basement/cover unconformities, discordant plutonic contacts, and simple fault systems, do not adequately explain domain juxtapositions. Relative displacement of adjacent crustal segments can account for the observed relationships.

Gneisses in continuous zones are interpreted as tectonically modified gneisses of adjacent domains. Mylonitization and evidence of other ductile shear phenomena are readily apparent in some zones; in others, recrystallization and migmatization obscure all but the coarsest ductile features. Features grade from obvious to subtle, abruptly across and gradually along strike. Regional geometry shows domains overlapping one another; displacement indicators point to northwestern overriding. Subsequent gravitational sinking may explain steep structures in overthrust mafic granulites. Repeated northeasterly, parallel straight-gneiss zones with NW-directed flat folds may indicate crustal stacking. A broad NW-marginal ductile zone suggests an allochthonous relationship between the Grenville marbles and the Central Gneiss Belt.

Pressure solution in the Gowganda Formation, Whitefish Falls, Ontario. Frank Fueten, Department of Geology, McMaster University, Hamilton, Ontario, Canada L8S 4M1.

A microscopic study of two samples of the Gowganda Formation, both having undergone pure shear deformation at greenschist facies metamorphism, allowed the following conclusions to be reached.

In sample A the reduction in quartz grain size, and pressure solution shadows are evidence for strong pressure solution activity. Prelithification fractures provided channelways for the removal of quartz and water out of the system. Matrix quartz was not recrystallized. In sample B there was extensive local recrystallization of quartz due to pressure solution activity related to metamorphic segregation and the formation of a cleavage. Cleavage in the matrix differs from that in an area of contact strain, produced by the buckling of a quartz vein. A comparison between the two samples suggests that water is necessary to produce metamorphic segregation and the system has to be closed to reach metamorphic segregation.

A plate tectonic model for the southwest end of the Foxe fold belt. J. R. Henderson, Geological Survey of Canada, 601 Booth Street, Ottawa, Canada K1A 0E8.

Cobbold & Quinquis (1980) demonstrated that sheath folds form in shear regimes, and may indicate relative sense of simple shear by S or Z asymmetry in *XZ* profile. Henderson (1981) described sheath folds in the Foxe fold belt, and concluded that asymmetrical S folds in the margins of the Lower Nappe suggest sinistral shear and southwest transport of the Upper Nappe. The Upper Nappe apparently moved southwest as a subhorizontal portion of the northern Archaean plate relative to the Archaean gneisses below and south of the fold belt. The folded sheets of Aphebian and Archaean gneisses composing the Foxe fold belt occur in a step-like ductile shear zone between the two plates of Archaean rocks: the 'risers' of the plate boundary zone step-up to the south and the horizontal 'tread' narrows westward. Traced farther west, the north and south steep zones (risers) apparently merge to form a single sinistral transcurrent shear zone between the plates. The model for the fold belt development suggests that the enveloping surface of the sinistral shear zone is gently N-dipping in the east and steepens progressively toward the west. The plate tectonic model requires a progressive westward increase of horizontal extension in the Foxe fold belt due to the westward tapering of the horizontal tread connecting the north and south risers of the step-like boundary. The progressive westward tightening and axial convergence of upright folds in the belt may be explained by the model.

Ellesmere–Greenland fold belt: structural evidence for left-lateral ductile shearing. H. Hugon, Department of Geology, University of Toronto, Toronto, Ontario, Canada M5S 1A1.

Regardless of whether they were passive or active markers of the Eurekan deformation, fold-axial traces in the Ellesmere–Greenland fold belt define a regional pattern typical of left-lateral ductile shear zones. It is postulated that a left-lateral mega-shear zone spanned the entire E–W width of Ellesmere Island plus adjacent North Greenland, and that the shear direction was subparallel to Nares Strait.

A left-lateral motion along Nares Strait is required by the plate tectonic models of J. T. Wilson and E. C. Bullard. To explain the opening of the Labrador Sea and Baffin Bay by sea-floor spreading, these models require a left-lateral displacement between Greenland and North America of 200–500 km. Because of the lack of lithological and structural offsets across Nares Strait, these models are controversial. The shear zone proposed here combines the contradictory evidence. Accordingly, a ductile behaviour of the rock masses permitted large left-lateral displacement of Greenland relative to North America without a large disruption of geological features.

Crustal structure of the Grenville-age Adirondack mountains, New York State: results from COCORP seismic reflection profiling. S. L. Klemperer, L. D. Brown, J. E. Oliver, C. J. Ando, B. L. Czuchra, R. A. Harris, S. Kaufman and D. Von Tish, Department of Geological Sciences, Cornell University, Ithaca, NY 14853, U.S.A.

Seismic reflection profiling by COCORP (Consortium for Continental Reflection Profiling) in the Adirondack mountains of northern New York has revealed good-quality reflectors in the upper and the lower crust, despite the extreme degree of deformation and metamorphism observed in this Precambrian terrane. A particularly prominent zone of layered reflectors lies between about 20 and 28 km beneath the Marcy anorthosite massif in the central Adirondacks. This layered sequence may represent igneous laminations, or lithologic variations within an originally sedimentary pile subsequently modified by metamorphism, or tectonic imbrication, or some combination of these effects. In particular, an interpretation of the prominent reflections as metasediments seems consistent with other available geophysical measurements, most notably those which demonstrate that a zone of high electrical conductivity exists at about the same depth as the layered reflections.

In contrast to the seismic profiles across the central and southeastern Adirondacks which are dominated by reflections in the lower half of the crust, two lines recorded in the northwestern Adirondacks show many discontinuous reflections from the upper and middle crust, but few reflections from the lower crust.

Down-plunge projection: a bridge between Precambrian and Mesozoic structures. Willem Langenberg, Alberta Geological Survey, Edmonton, Alberta, Canada T6H 5R7.

Computer-assisted mapping has been a powerful tool in unraveling complex structures in the Precambrian Shield of northeastern Alberta, as well as the structure of coal-bearing strata in the Alberta Foothills. Down-plunge projection forms the foundation of a computer package for storing, retrieving and displaying geological data. Retrieved data can be displayed on maps of any scale. Cylindrical domains are established and geological cross-sections obtained. Orientation diagrams can be plotted and structure-contour maps of individual horizons can be displayed.

Aphebian granitoids of northeastern Alberta show a dome and basin geometry. These domes are generally immature diapirs. Parts of the domes and basins fit a cylindrical fold model, while other parts fit a conical fold model.

Mesozoic coal-bearing strata of the Alberta foothills show folds and faults. Folding is of the flexural-slip variety that results in chevron folds of the competent sandstone layers between more incompetent material. Disharmony of shale and coal horizons resulted in tectonic thickening of coal in anticlines. Most faults are SW-dipping thrust faults. NE-dipping reverse faults are generally younger than the thrusting.

Characteristics of Grenville mylonites, and considerations of strain in shear zones. Christopher K. Mawer, Department of Geology, University of New Brunswick, Fredericton, New Brunswick, Canada E3B 5A3.

The rocks of the tectonic boundary zones occurring in the Grenville Province of central Ontario possess a distinctive assemblage of structural features; these boundary zones are major ductile shear zones, and the rocks are mylonites.

Mesoscopically, pervasive schistosity and lineation, less-deformed tectonic 'inclusions', boudinage of layers, rotated porphyroclasts with long, recrystallized 'tails', shear band cleavage and sheath folds are observed in the mylonites, but not in the host rocks. Microscopically, the shear zone rocks are also quite distinct. They are mostly or totally dynamically recrystallized, possess pronounced dimensional preferred orientation of elongate mineral grains and aggregates, and exhibit strong asymmetric crystallographic preferred orientations of quartz and mica. These features do not occur in the host gneisses.

Calculations indicate that the mylonites have probably suffered simple shear strains in excess of $\gamma = 50$ and extensions of originally orthogonal marker lines in excess of 4000%. These values would rise dramatically if, as is likely, there is a flattening component in the deformation. The rocks do not record these strains totally, due to the ductile and synmetamorphic nature of the shear zones. Dynamic recrystallization is extremely efficient at reducing grain aspect ratios and sizes, leading to the removal of evidence of large strains. It is considered that many of these rocks possess a steady-state foliation.

Mesoscopic and microscopic structures from these shear zones and structural polarity from reclined folds in the host rocks indicate NW-directed overthrust motion across a large area of the Grenville Province, which is considered to be a deep-level imbricated stack of overstepped nappes.

Three-dimensional strain in analogue models of tectonic structures. John Morgan, Geology Department, University of Toronto, 170 College St., Toronto, Canada M5S 1A1.

A new method has been developed for computing the spatial distribution of three-dimensional strain in analogue models of non-cylindrical, non-axisymmetric tectonic structures. Strain may be calculated at any point midway between serial sections.

The strain markers are passive and in the shape of cubes or rectangular prisms. They make up a grid consisting of three families of contacts between layers of cubes or prisms. After a model is serially sectioned, the state of strain at a point between the sections is calculated using the local orientation and spacing of the contacts. The local inclination of the contacts with respect to the direction of sectioning is determined using the displacement of the contacts between the serial sections on either side of the point where strain is being calculated. Other components of the orientation and spacing of the contacts are obtained from individual section surfaces.

This information is combined to give the transformation coefficients for the strain in the neighbourhood of a point. From these coefficients the strain ellipsoid is easily obtained.

Sigmoidal K-feldspar augen as indicators of sense of tectonic transport. L. Nadeau, Department of Geology, Carleton University, Ottawa, Canada K1S 5B6.

Recently recognized shear zones in the Grenville Province, Canadian Shield, carry numerous scattered K-feldspar augen. When viewed in an *XZ* section, these show a rotation angle exceeding ninety degrees about an axis lying in the shear plane and perpendicular to the mineral stretching lineation, and are commonly ornamented with asymmetrical wrapping tails (Davidson *et al.* 1982).

Such augen also occur in thin mylonitic layers formed in the central part of mesoscopic shear zones as well as in a sheared pegmatite. In both cases, approaching these mylonitic layers, the foliation in the host rocks becomes more intensely developed and its progressive rotation towards the shear plane results in gross parallelism of both planar elements and permits the determination of the shear sense. In the case of the sheared pegmatite, the zone of parallel schistosity and mylonitic foliation also hosts well-developed shear bands indicating the same shear sense. Moreover, the drag pattern of the foliation around the augen is similar to that produced experimentally during the rotation of a cylindrical body under a simple shear regime (Ghosh & Ramberg 1976). In all cases, K-feldspar augen showing clockwise and anticlockwise rotation were developed in dextral and sinistral shear zones, respectively.

The Shuswap Metamorphic Complex: its role in Cordilleran tectonism. Andrew V. Okulitch, Geological Survey of Canada, 3303 33rd St. NW, Calgary, Canada.

The Shuswap Complex consists of three parts, each with a unique stratigraphy and orogenic evolution, separated by major faults of diverse nature and having in common only a post-late Mesozoic tectonic history. The Monashee Complex, exposed in the domal nappes of Frenchman Cap and Thor–Odin, is a para-autochthonous part of the Precambrian Shield. The Monashee décollement, a warped mylonite zone interpreted as a regional thrust fault active through the Middle Jurassic to Late Cretaceous, separates this complex from metamorphic rocks correlative with late Proterozoic to early Mesozoic strata of the Kootenay Arc and Cariboo Mountains. The Okanagan Complex, straddling the 49th parallel from the Okanagan Valley to the Kootenay Arc, contains the exhumed roots of a Mesozoic magmatic arc built upon North American continental and transitional crust that includes accreted late Palaeozoic oceanic and volcanic arc terranes.

The Eastern Cordillera formed during westward drift of the craton into a continent of accreted elements. Response of the craton, attenuated during two episodes of Proterozoic rifting, and its bordering sedimentary prism to underthrusting and simultaneous collision was to restore attenuated crust to about its original thickness while deforming the westernmost parts of the bordering prism (Jurassic) strata eastward (Late Cretaceous–Palaeocene). Waning westward underthrusting led to ascendancy of transcurrent faulting in response to northward drift of the Pacific plate, crustal extension primarily in the Okanagan Complex and final uplift and denudation of cratonic massifs.

Structure of southern and north-central Ellesmere Island, N.W.T. Andrew V. Okulitch and Kirk G. Osadetz, Geological Survey of Canada, Calgary, Canada.

Structural studies in the Baumann and Vendom fiords area of southern Ellesmere Island, and in the Ekblaw Lake area of north-central Ellesmere Island, have revealed two episodes of compressive orogenic activity. Tight folds and reverse faults, influenced by detachment on Ordovician evaporitic horizons, formed in the south during the Ellesmerian Orogeny of latest Devonian or earliest Carboniferous inception. The intensity of deformation is indicated by the profound structural relief below the Late Carboniferous unconformity. In the north, tight folds and penetrative cleavage affected strata of the Cambrian Grant Land Formation prior to deposition of Carboniferous rocks.

Late Palaeogene Eurekan deformation accentuated Ellesmerian structures and cut them by cratonward-directed thrust faults. A model of thin-skinned overthrusting appears appropriate for both study areas, and probably applies to most of the Central Ellesmere and Hazen fold belts. This model emphasises the compressive nature of both orogenies and contrasts with previous suggestions which favoured normal faulting and differential uplift as well as compression to form observed structural elements.

Chlorite–mica aggregates in very low grade rocks. Ben van der Pluijm, Department of Geology, University of New Brunswick, Fredericton, New Brunswick, Canada E3B 5A3.

Chlorite–mica aggregates in slates from various parts of a fold show different morphologies, dependent on the operating deformation mechanism. From the limb to the hinge, rigid-body rotation becomes less important and folding and intragranular kinking are more common. This is associated with an increasing aspect ratio (width/length) of the aggregates.

Chlorite–mica aggregates are statistically parallel to local bedding. Variation in degree of distortion of chlorite suggests continuous solution and growth during deformation. Muscovite is generally more highly deformed, suggesting that it was all early. Splitting of detrital micas along (001)-planes occurs when the dihedral angles between bedding and cleavage are high, creating extension sites where mimetic growth of chlorite can take place. Thus an early diagenetic/metamorphic formation is favoured for the origin of the aggregates.

The behaviour of the aggregates during deformation provides information on a mechanism for cleavage development. As a result of intragranular kinking high-angle boundaries are created, with parts of the deformed grains at a low angle to the cleavage plane (cf. Etheridge & Hobbs 1974, Williams *et al.* 1977). This is further modified by recrystallization, solution and growth to give the observed microstructure.

Flow stresses from syntectonically recrystallized grain size: some additional uncertainties. G. Ranalli, Department of Geology, Carleton University, Ottawa, Ontario, Canada K1S 5B6.

Empirically calibrated grain size-stress relations are widely used to infer flow stresses in tectonites. The validity of the procedure is predicated on the assumption that during steady-state creep the back stress on a dislocation, caused by interaction with neighbouring dislocations, is equal to the externally applied stress; that is the local stress is equal to the tectonic stress.

It is shown here that, since grain size adjusts locally to the local stress, and the latter is a stochastic variable which shows random variations from the value of the applied stress, the distribution of local stress, and consequently of grain size, can be expected to be lognormal on the basis of simple probabilistic considerations. This inference is confirmed by observations in both metals and rocks.

In a log-normal distribution, the mean value of the linear (untransformed) variable depends not only on the central tendency of the distribution, but also on its dispersion: consequently, a more appropriate measure to be used in this case is the median grain size. Use of the arithmetic mean may lead to erroneous estimates of stress unless the coefficient of variation of both calibrating rock sample and field sample is the same. The magnitude of the stress error has been computed as a function of these parameters.

Algebraic calculation of two-dimensional strain from center-point distribution data. P.-Y. F. Robin. J. Tuzo Wilson Research Laboratories, Erindale Campus, University of Toronto, Mississauga, Ontario, Canada L5L 1C6.

Once a distribution of center-points on a section has been judged suitable for estimating strain, that strain can be calculated algebraically rather than estimated visually. Consider an All-Center Plot (ACP; Fry 1979), restricted as follows. (1) Only the points which fall within a radius R of the center are kept on the ACP, where R is large enough for the point of density of the ACP to be uniform at that distance. (2) Only the centers which are further than R from the edge of the areal domain over which data are collected are 'brought' to the center of the ACP for constructing that ACP. Note that this ACP need not be actually plotted.

Let x_i and y_i be the coordinates of a point i of the ACP. We calculate the following symmetric matrix by summing over all points of the ACP:

$$\begin{bmatrix} \sum x_i^2 & \sum x_i y_i \\ \sum x_i y_i & \sum y_i^2 \end{bmatrix}.$$

Eigenvectors give the principal directions of strain. The eigenvalues, S_1 and S_2, give the ratio of principal quadratic elongations as

$$\lambda_1/\lambda_2 = (S_1 - NR^2/4)/(S_2 - NR^2/4),$$

where N is the number of points on the ACP. More experiments on artificial samples of known strain are underway to test the reliability of the method.

Plagioclase flow mechanisms in deformed anorthositic rocks. D. H. Rousell, Department of Geology, Laurentian University, Sudbury, Ontario, Canada P3E 2C6.

Examples are given of four flow mechanisms; all, except the Sogn Jotun nappe, are from the Grenville Province. At Lac Rouvray, Quebec (Kehlebeck 1972) cataclastic textures predominate in the least deformed rocks; the most deformed rocks are recrystallized. Plagioclase displays a series of textural changes as very coarse-grained igneous rocks are transformed into medium-grained gneissic rocks. In the Sogn Jotun nappe, Norway (Bouillier & Gueguen 1975) plagioclase porphyroclasts are recrystallized to a small grain size and greatly elongated by superplastic flow. In the Wanapitei complex, Ontario, the crystal lattices of secondary plagioclase grains are bent by as much as 27°. Mechanical twins occur at grain boundaries and formed prior to bending. The lack of registry between atomic planes may have been taken up by 'geometrically necessary' edge dislocations. The St. Charles sill, Ontario (Rousell 1981) displays interlayered massive and gneissic rocks. Plagioclase in massive layers is coarse grained and euhedral; in gneissic layers it is fine grained, and primary grains are partly replaced by elongate anhedral grains. New grains formed by grain-boundary migration and Coble creep (strain rate inversely proportional to grain size). A gneissosity developed in the finer-grained primary layers while coarse-grained layers remained undeformed.

Correlation between strain patterns and large-scale flow structures in flat Precambrian terrain. W. M. Schwerdtner, Department of Geology, University of Toronto, Toronto, Canada M5S 1A1.

The ductile regimes of many Precambrian shields are characterized by flow structures in the boundaries of contrasting lithic units. These lithic units may contain prominent strain fabrics whose relative age with respect to the flow structures must be established before making geodynamic interpretations.

An objective method is required to ascertain which elements (if any) of the strain patterns predate their host structure. Owing to a lack of topographic relief, it is rarely feasible to remove the total rotational strain and test whether this operation also removes the host structure. But it may be possible to judge from the symmetry of the total-strain pattern whether the host structure has a chance of being removed completely. For example, the development of upright domes and/or circular basins from plane-parallel units leads to strain patterns which, like the structures themselves, are characterized by vertical radial symmetry (an infinite number of vertical symmetry planes). Most subcircular domes and basins studied in the gneiss terrains of Ontario have total-strain patterns of lower symmetry. As suggested independently by incremental strain features, a large portion of the total strain is older than the subcircular structures.

Calculations of intersection lines and of fold axes based on the Bengtson tangent diagram. P. S. Simony, University of Calgary, Calgary, Alberta, Canada T2N 1N4.

The orientation of a linear element (lineation, dip vector, etc.) is given by a vector with trend (azimuth) θ and with length proportional to tan ϕ, the tangent of the plunge or dip. The terminus of this vector has the polar coordinates (θ, tan ϕ) and the Cartesian coordinates (x, y) where the x-axis is north, the y-axis is east.

Bengtson (1980), showed that the attitude of the intersection of two planes is given graphically by the normal from the origin to the straight line joining the points (x_1, y_1) and (x_2, y_2) representing the two planes. That normal to the straight line $y = mx + b$, which joins the two points, has trend n and plunge p, where:

$$\tan n = -\frac{1}{m} = \frac{x_2 - x_1}{y_1 - y_2}$$

and

$$\tan p = b \cdot \cos(\arctan m).$$

In conical folds, the attitude of each local β-line is calculated from the intersection of suitable bedding planes for each portion of the fold (Stockwell 1950). In cylindrical folds, the β-lines are all parallel and the dip vectors scatter along a straight line that can be estimated by the reduced major axis, $y = mx + b$ (Imbrie 1956), where:

$$m = \sigma y/\sigma x$$

and

$$b = \bar{y} - m\bar{x}.$$

Modern pocket calculators with routines for polar to Cartesian conversion and for the calculation of means and standard deviations, make these calculations easy, even in the field.

Evolution of an early Proterozoic mantled gneiss dome, southwest Finland. Cees van Staal, Department of Geology, University of New Brunswick, Fredericton, New Brunswick, Canada E3B 5A3.

A dome-shaped body in Svecofennian upper amphibolite facies supra- and infracrustal rocks on Kemiö Island resembles the classical mantled gneiss dome in that it comprises a core and a mantle but differs in that the intrusive granitoids occur in the mantle rather than the core.

Four generations of folds are recognized, and structural and petrological evidence, that is pressure inversion from core to mantle, indicate an F_2-related thrusting origin for the discontinuity that separates core from mantle.

The dome structure is explained as an interference structure resulting from superposition of F_3 and F_4 folding. A possible origin by diapirism cannot be eliminated but there is no evidence to invoke such a process. Finally, the structural and metamorphic history of this area might have large implications for the tectonic history of the well known Kemiö–Orijärvi supracrustal belt.

Sampling constraints on petrofabric analysis by X-ray diffraction. John Starkey, University of Western Ontario, London, Ontario, Canada N6A 3B7.

The orientations of crystals in rocks can be determined by X-ray diffraction using either the fabric camera (Starkey 1964, 1974) or the texture goniometer (Decker *et al.* 1948, Schulz 1949a, b).

With the fabric camera the complete orientation data for a selected crystallographic plane are determined from a petrographic thin section during a single exposure. Hence, the data are obtained from a single sample of crystals. This sample remains essentially constant for each plane measured. Furthermore, since the Bragg reflections from all the crystals in the sample are recorded on the film there is no upper limit on the size of grains which can be analysed. The inherent sensitivity of film limits the lower grain size to approximately 10 μm.

With the texture goniometer the specimen must be reset between the collection of data in the transmission and reflection modes, thus, even for an individual crystal plane the data are obtained from two samples of crystals. The sampling problem is much worse if two completely different specimens are used to collect the transmitted and reflected data, as is the common practice. In addition, since the detector must follow a prescribed path in space, the Bragg reflections from only some of the crystals in the irradiated volume of the specimen are recorded. This effectively limits the maximum grain size suitable for analysis to approximately 100 μm.

Induced micro-fracturing in cores from a deep borehole in the Lac du Bonnet Granite, Manitoba. R. M. Stesky, Earth and Planetary Sciences, University of Toronto, Erindale Campus, Mississauga, Ontario, Canada L5L 1C6 and P. J. Chernis, Atomic Energy of Canada Ltd., Whiteshell Nuclear Research Establishment, Pinawa, Manibota, Canada R0E 1L0.

Core samples were taken at various depths to 928 m from a granite batholith. SEM observation indicates that the deep samples contain fresh, large aperture (several micrometres), tapered cracks that do not occur in the shallow samples (above 400 m depth). The cracks have irregular, but well-matching surfaces and resemble dilatant cracks formed during the stressing of a brittle rock. The presence of these cracks has a marked effect on the physical properties of the samples. Permeability and compressibility are enhanced and low-pressure seismic velocities are lowered, although they are restored to nearly constant values with depth when the overburden pressure is restored to the samples. Using the Walsh–Grosenbaugh analysis, we find that these cracks close fairly abruptly at a characteristic pressure that increases with the depth of sampling. Comparison with preliminary in-situ stress measurements made in the same hole suggests that the closure pressure is approximately the same as the maximum horizontal stress, typically about twice the vertical stress. We suggest that the micro-fractures are dilatant cracks formed during drilling by the stresses at the end of the borehole. The cracks occur in the core and perhaps in the wall rock, and will have a major impact on the interpretation of physical properties of the rock body obtained from laboratory measurements of cores and possibly from borehole logs sensitive to the borehole-wall properties, such as focused-beam-electric and neutron–neutron logs.

Morphology of 'isolated' epidote faults in the Eye–Dashwa pluton, Atikokan, Ontario. Denver Stone, Atomic Energy of Canada, 601 Booth Street, Ottawa, Canada K1A 0E8.

'Isolated' epidote faults in the Eye–Dashwa granite pluton are defined as faults which contain the mineral epidote and are not members of a closely spaced array of faults or intersecting faults. The majority of 'isolated' epidote faults have straight central segments but curve and splay towards the receding side at both ends. Mean curvature of the splays is 32.3°. Right-handed 'isolated' epidote faults tend to strike 290 ± 20° and dip 75 ±15°. Left-handed 'isolated' epidote faults tend to strike 010 ± 20° and dip 80 ± 10°. Regularly spaced measurements along the surface traces of these faults indicate that median fault width (w) increases with length (L) such that $w \simeq 7.02 \times 10^{-5}L$ for $L < 100$ m. w increases with displacement (D) such that $w \simeq 0.0131D + 0.3$ for $D < 1$ m. The total length of splays (Ls) or, in effect, the abundance of secondary fractures associated with the ends of 'isolated' epidote faults increases with fault displacement where $Ls \simeq 0.5D + (0.367D)^2$ for $D < 10.0$ (units of Ls are m × 100.0 and units of D are m × 0.1). Orientation and width can be measured from oriented drill core and used to estimate length, displacement and general shape of 'isolated' epidote faults.

Strain domains and their boundaries in an Archaean greenstone belt, northwestern Ontario. G. M. Stott, Precambrian Section, Ontario Geological Survey, 77 Grenville St., Toronto, Ontario, Canada M5S 1B3.

The Shebandowan greenstone belt comprises discrete megascopic domains of contrasting tectonic strain with domain boundaries trending subparallel to the length of the E–W trending belt. The dominant domain, D_1, formerly extended across the width of the belt and is attributable to granitoid diapirism south of the belt. D_1 is characterized by pronounced westerly-plunging mineral lineations. Other domains, of D_2 deformation superimposed on D_1, are characterized by gentle easterly-plunging mineral lineations and a more pronounced schistosity. D_2 dominates the northern one-third of the Shebandowan belt and extends northward across the adjacent Quetico metasedimentary subprovince. It is attributable to regional subhorizontal shortening.

Strain domain boundaries (S.D.B.) separate D_1 and D_2 domains of contrasting mineral lineation orientations. S.D.B.'s are sharp, with no evidence of dislocation. Regionally distributed measurements of magnetic susceptibility anisotropy (M.S.A.) plus a detailed section across one S.D.B. demonstrate the contrast in the prolateness of anisotropy and principal direction of extensional strain between the domains. However, the effects of D_2 are shown by M.S.A. to go beyond the S.D.B. Within 150 m of a major S.D.B., the M.S.A. of D_1 domain reflects an increased flattening strain that contrasts with the more prolate anisotropy of strain typical of D_1.

Modelling of structures in uniformly layered crustal systems with a 20,000 g centrifuge. J. M. Summers, J. M. Dixon, D. Medwedeff and M. Timlin. Department of Geological Sciences, Queen's University, Kingston, Ontario, Canada K7L 3N6.

The development of large-scale structures in uniformly layered crustal rock systems has been studied with centrifuged models. Microlaminated model materials (alternating silicon polymers and modelling clays), with controlled layer-thickness ratios, layer thicknesses ≥15 μm, and controlled ductility contrasts in the range 1:1 to 1000:1 permit detailed modelling of aspects of deformation of km-scale prototype rock multilayers with internal layering on the scale of 5–50 m. Multilayer deformation has been studied for a range of relatively simple, but geologically representative, boundary conditions.

Similarity between experimental structures and natural structures is striking. Analysis of geometric and dynamic scaling indicates that the similarity reflects the accuracy of scaling of physical parameters controlling deformation.

Under layer-parallel contraction, folds develop non-synchronously in isolation or at the front of serially propagating fold trains. Individual structures initiate as periclines which amplify, increase in axial length and interfere with adjacent structures.

Under layer-parallel extension, deformation is concentrated in a network of conjugate shear zones which envelope undeformed multilayer pods. Continued extension involves rotation of shear zone boundaries, relative rotation between adjacent relict domains, propagation of new shear zones, and finally the production of a totally disrupted mélange-like assemblage of competent blocks in an incompetent matrix.

Structural development along a segment of the Cobequid fault, Nova Scotia. Joseph C. White, Department of Geology, University of New Brunswick, Fredericton, New Brunswick, Canada E3B 5A3.

A segment of the Cobequid fault exposed in Greville Bay, Nova Scotia has been examined to determine the deformation processes and the relationship between localized and larger-scale fault structures. The fault zone consists of lithologically contrasting foliated fault blocks which contain breccia and gouge zones. The steep foliation within these blocks shows little evidence of preserved primary features in contrast to similar rocks outside the fault zone. This, in conjunction with the development of sheath folds with subhorizontal axes suggests that the oldest foliation developed during strike–slip movement.

The younger breccia and gouge zones, contain consistent patterns of internal shears and rotated fragments on the metre to millimetre scale. Comparisons of these patterns with displaced marker horizons and experimental gouge studies indicate pervasive dextral slip along these zones. Lineations within these zones plunge 8–25° east indicating predominantly strike–slip movement. The overall geometry of the zones suggests major dextral slip parallel to zone boundaries with secondary dextral slip faults oblique to the main movement direction, accommodating deformation within the zone.

Preliminary view of the development of a gneiss complex in the western part of the Ontario gneiss segment, Grenville Province. Howard Williams, Brock University, St. Catharines, Ontario, Canada L2S SA1.

The coastal area between Point Au Baril and Olwyn Island on Georgian Bay consists predominantly of an inhomogeneously deformed and migmatized series of meta-igneous rocks, including the

Britt Pluton and the Hangdog Complex, intrusive into a subordinate deformed and migmatized supracrustal sequence of basic, calcareous and psammitic compositions. The intrusives were originally coarse, often feldspar-megacrystic, dominantly granitoid bodies, with a calc–alkaline compositional range from coarse coronite gabbro to granite. Basic and basic inclusion-rich intermediate variants are volumetrically insignificant often occurring in marginal, inclusion-rich zones of the larger, generally granitic bodies such as the Britt Pluton.

Cutting both the Britt and Hangdog bodies are swarms of basic dykes usually with coarse granulite-facies centres and amphibolite-facies margins. Two types of net-veined basic intrusions occur within and beside the Britt Pluton, and in the earlier granitoids of the Hangdog Complex.

All the rocks in the area other than late-stage granitic pegmatites have been subjected to a regional deformation resulting in the development of a pervasive gentle NW- or SE-plunging strong lineation and highly non-cylindrical mesoscopic folds. These in turn are deformed by sporadic tight upright NE-trending structures and multitudes of frequently non-planar shear zones of numerous orientations.

Rotation and foliation development. P. F. Williams, Department of Geology, University of New Brunswick, Fredericton, New Brunswick, Canada E3B 5A3.

A foliation previously described as a product of soft sediment deformation (Pajari *et al.* 1979) is shown to have developed after the peak of metamorphism. Various processes have been responsible for development of the foliation but basically all are dependent primarily on rotation, enhanced in some cases by mimetic growth. 'Pressure solution' does not appear to have been important and this possibly reflects 'dry' conditions during retrograde metamorphism.

In shale beds, the foliation is a product of transposition by crenulation or kinking of an earlier bedding-parallel foliation. Locally new micas have grown along the axial surfaces of the micro-folds and their preferred orientation is attributed to mimetic growth (see Etheridge & Hobbs 1974).

In coarser clastic sediments, rich in shale clasts, the foliation is defined by the preferred dimensional orientation of the clasts. Presence of bedding within the clasts makes it possible to ascertain that the preferred orientation of some has been achieved by rotation whereas others have been flattened and the internal bedding foliation transposed into a new foliation identical to that in the shale beds. Most clasts however, have combined both rotation and flattening.

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