# THE EXTERNIDES OF WOPMAY OROGEN, POINT LAKE AND KIKERK LAKE MAP AREAS, DISTRICT OF MACKENZIE

Project 810021

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**Abstract**

*Some results of recent field work are briefly discussed as they pertain to the following topics: (1) north-south stratigraphic continuity of the Precambrian continental-terrace wedge, (2) stromatolite elongation, paleowind direction and global polarity during deposition of the Rocknest dolomite shelf, (3) evidence for primary aragonitic mineralogy of the Rocknest Formation, (4) attempted quantitative paleobathymetry of the upper continental slope, (5) eastward migration of foredeep flysch, (6) nature of basement involvement in Asiak Fold-Thrust Belt, (7) relation of thrusting to the foredeep molasse, (8) mysterious basement-involved cross folding of regional extent, (9) normal faults associated with late transcurrent faulting, and (10) the first reported minor lead-zinc vein mineralization in Rocknest dolomite. Future field work is outlined.*

## Introduction

The externides of Wopmay Orogen include the Asiak Fold-Thrust Belt and the autochthonous basins located between the frontal thrusts and cratonic basement of the Slave Province (Fig. 60.1). In 1981, a three-year project was initiated to study the externides in the Point Lake (86H), Takijuq Lake (86I), Kikerk Lake (86P) and Coppermine (86O) map areas, with special emphasis on the stratigraphy and structure of the Epworth Group (Odjick and Rocknest formations). This group constitutes the remnants of an immature, west-facing, continental terrace of Atlantic type that onlaps the Archean basement. It underlies the Recluse Group, which consists of orogenic flysch and other sediments deposited in a foredeep that migrated eastward in front of the evolving fold-thrust belt and which ultimately was incorporated partly within it. This deformation may be related to collision of the "Coronation Margin" with a microcontinent (Hoffman, 1980), possibly the Hottah Terrane (Hildebrand et al., 1983), and attempted subduction of the margin beneath it.

In 1982, field work was concentrated near the ends of the fold-thrust belt, specifically east of the Carousel basement massif in the south and around the intersection of Kikerk Thrust and the Tree River Fold Belt in the north (Fig. 60.1). This report summarizes some of the more significant findings, including the discovery of rare galena-sphalerite veins in dolomite of the Rocknest Formation.

## Original Continuity of the Continental Margin

A striking feature of Wopmay Orogen is the virtual absence of externides in the south half (south of 65°25'N latitude) of the orogen. Is this due simply to deeper erosion in the south and consequent removal of the thin-skinned externides, or does it reflect an original change in character of the continental margin? For example, a drastic thinning of the marginal sedimentary prism would be expected in passing from an embayment to a promontory of a continent, or from a rifted to a sheared segment of its margin.

Any original change in character along the continental margin should be reflected by north-south variation in stratigraphy or facies of the Epworth Group in the north half of the orogen. No such variation is apparent. The basic three-fold subdivision of the shelf-facies Odjick Formation persists the length of the belt (i.e. lower member mainly laminated argillite, middle member stacked coarsening-upward cycles of semipelite and quartzite, upper member semipelite with numerous ferruginous and intraclastic dolomite beds transitional into the overlying Rocknest Formation). Although a snow-white quartzite and megacrystic mafic sills and flows in the lower member are seen only at the south end, mainly in the autochthonous mantle of Carousel Massif, no autochthonous strata are exposed on strike to the north.

North-south correlations in the Rocknest Formation are even more impressive. Not only do its ten members persist virtually unchanged along strike, but many individual shale-dolomite cycles (Hoffman, 1975), 2-5 m thick, do so as well. In Member 4, for example, all seventeen cycles present appear to correlate from one end of the belt to the other, a distance of 215 km. Thus, there is no evidence of change in the original character of the margin from north to south. An explanation for the absence of externides in the south half of the orogen must therefore be sought in deeper erosion or a thinner Recluse Group in the south.

## Stromatolite Elongation, Paleowinds and Global Polarity

Strongly elongate stromatolites in the Rocknest Formation are consistently oriented northeast-southwest, both at the shelf edge and throughout all of the externides. Even after tectonic rotations related to the late conjugate transcurrent faults are removed, the elongation remains quite oblique to the shelf edge, which is surprising. Locally, especially in the Tree River Fold Belt, the elongation may be enhanced by penetrative tectonic strain, but this cannot be true in most places because ooids and other stromatolites are generally very weakly strained. The most plausible explanation may be that the elongation parallels the prevailing paleowind direction.

There are no paleomagnetic data for the Rocknest Formation itself, but paleolatitudes for the central Rocknest shelf area before and after Rocknest deposition can be deduced from paleopoles obtained by Evans and Hoye (1981) for rocks correlative with the Odjick Formation (Western River Formation) and lower Recluse Group (Akaitcho River and Mara formations). The resulting paleolatitudes are 10 degrees in Odjick time and 16-17 degrees in early Recluse time. The Rocknest Formation was probably also deposited within the low-latitude belt of trade winds (10-30 degrees), consistent with the paleowind hypothesis.

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The paleomagnetic measurements are ambiguous as to polarity and this has led to controversy in tectonic interpretation of the data (e.g. Cavanaugh and Seyfert, 1977; Irving and McGlynn, 1979). The ambiguity can be resolved if the paleowind hypothesis is correct because the low-latitude trade winds blow from the northeast in the northern hemisphere and southeast in the southern hemisphere. As all paleopoles for the Coronation Supergroup and its correlatives project near South America (Irving and McGlynn, 1979; Evans and Hoye, 1981), trade winds would have blown from the southwest (present day co-ordinates), consistent with the observed stromatolite orientation, if the Rocknest shelf were in the northern hemisphere but from the southeast (present day co-ordinates) if the shelf was antipodean.

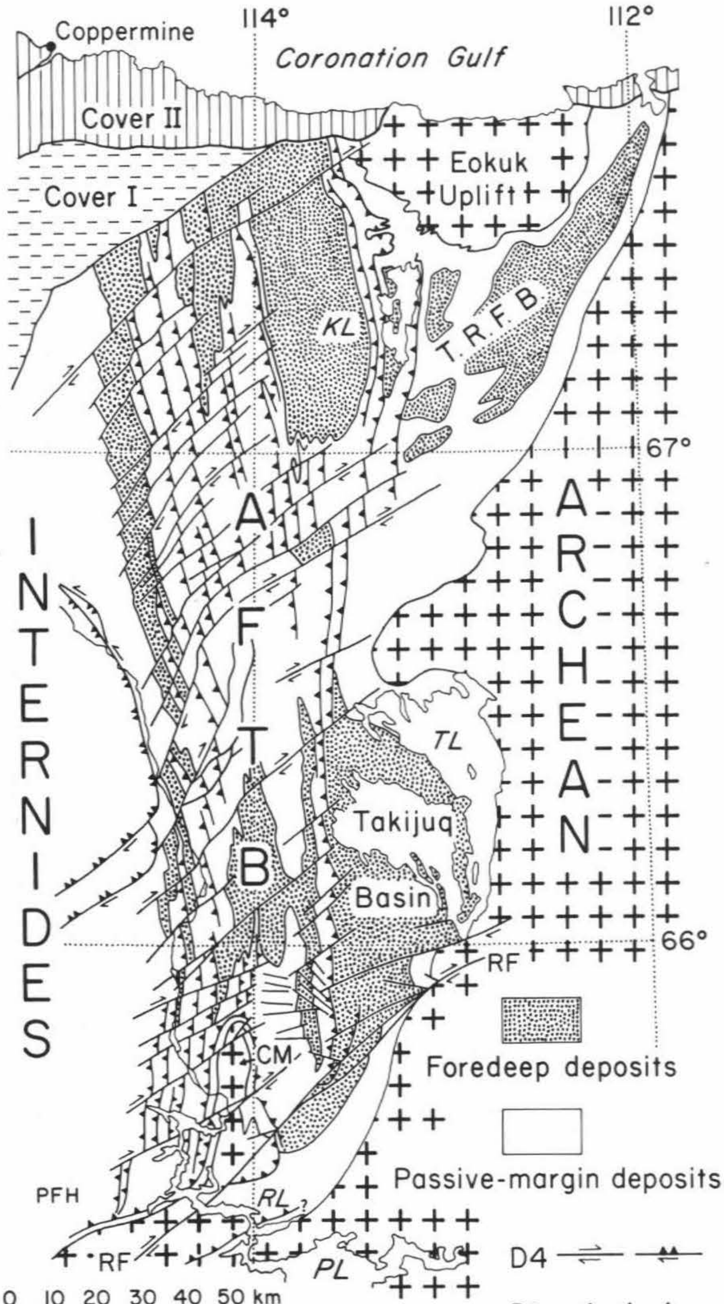


*Figure 60.1. The externides of Wopmay Orogen. AFTB, Asiak Fold-Thrust Belt; TRFB, Tree River Fold Belt; CM, Carousel Massif; RF, Redrock Fault; KL, Kikerk Lake; TL, Takijuq Lake; RL, Redrock Lake; PL, Point Lake.*

The prevalence of onshore not offshore winds is also consistent with the notably starved fore-slope facies of the Rocknest Formation. Irving and McGlynn's (1979) treatment of the Coronation paleopoles as north poles is therefore supported.

### Evidence that some Rocknest Dolomite was Originally Aragonite

Aragonite is the dominant carbonate mineral precipitated in modern oceans but the abundance of dolomite in the Precambrian with well preserved primary features, the Rocknest Formation for example (Hoffman, 1973, Fig. 6c), has prompted renewed interest in the possibility of primary Precambrian dolomite (Tucker, 1982). Aragonite, being metastable under near-surface conditions, is inevitably replaced during diagenesis and it is generally too fine grained to leave recognizable pseudomorphs. An exception is the coarsely crystalline botryoidal aragonite cement found in active Holocene reefs (Ginsburg and James, 1976) and recognized as pseudomorphs in some older Phanerozoic reefs and associated facies (e.g. Assereto and Kendall, 1977, Fig. 19).

Well preserved silica pseudomorphs of botryoidal aragonite (Fig. 60.2) associated with tepee structures were found in peri-reefal facies near the Rocknest shelf edge (Grotzinger and Read, in press). They occur in a muddy, locally cryptalgalaminated facies that overlies crossbedded ooid and intraclast grainstone (dolomitized back-reef sands), which in turn overlies and occurs landward of a stromatolite boundstone reef facies that forms a 1 km thick rim to the carbonate continental shelf.

The silica pseudomorphs show that the aragonite botryoids grew downwards into cavities from the undersides of tepees. They are up to 3 cm in diameter and form discontinuous sheets. Where unsilicified, the botryoids are only faintly visible as poorly defined radiating fibrous structures in medium anhedral dolomite (0.2 to 0.8 mm crystals) and may be outlined by patchy chalcedony. However, well silicified botryoids have clearly defined, radiating needle fibres that project downwards from growth points on the undersides of tepees. The botryoids have smoothly curved undersides and the fibres appear to have been orthorhombic. Silicified botryoids consist of chalcedony, growing inward from the fibre margins (outlined by dolomite euhedra) in small radiating masses (up to 0.5 mm) that pass toward the interior of fibres into a coarser (0.2-0.4 mm) anhedral mosaic of quartz.

Other features in the Rocknest Formation indicative of primary aragonite are silicified ooids with well developed concentric coatings, and tufa-like cryptalgalaminites that contain square-tipped needle fibres outlined by mud drapes (microbially precipitated aragonite tufas?). There may be no need, therefore, to account for primary Precambrian dolomite by invoking differences in seawater chemistry (Tucker, 1982) but the problem of secondary dolomitization without destruction of primary features remains.

### Quantitative Paleobathymetry of the Upper Continental Slope

A continuous syncline of Recluse Group flysch, 165 km in length and 2-10 km in width, occurs just west of the Rocknest shelf edge (Fig. 60.1). The fold is segmented by late transcurrent faults and plunges gently to the north. Numerous turbidite beds can be observed to close around the fold hinge, assuring that the hinge is not faulted. The fold invariably has contrasting facies of Rocknest Formation on its two limbs. The west limb has a starved sequence of slope-facies dolomite rhythmites and rhythmite breccias, whereas the east limb has thicker, more proximal, slope-facies rhythmite that interfingers with reefal shelf-edge facies.

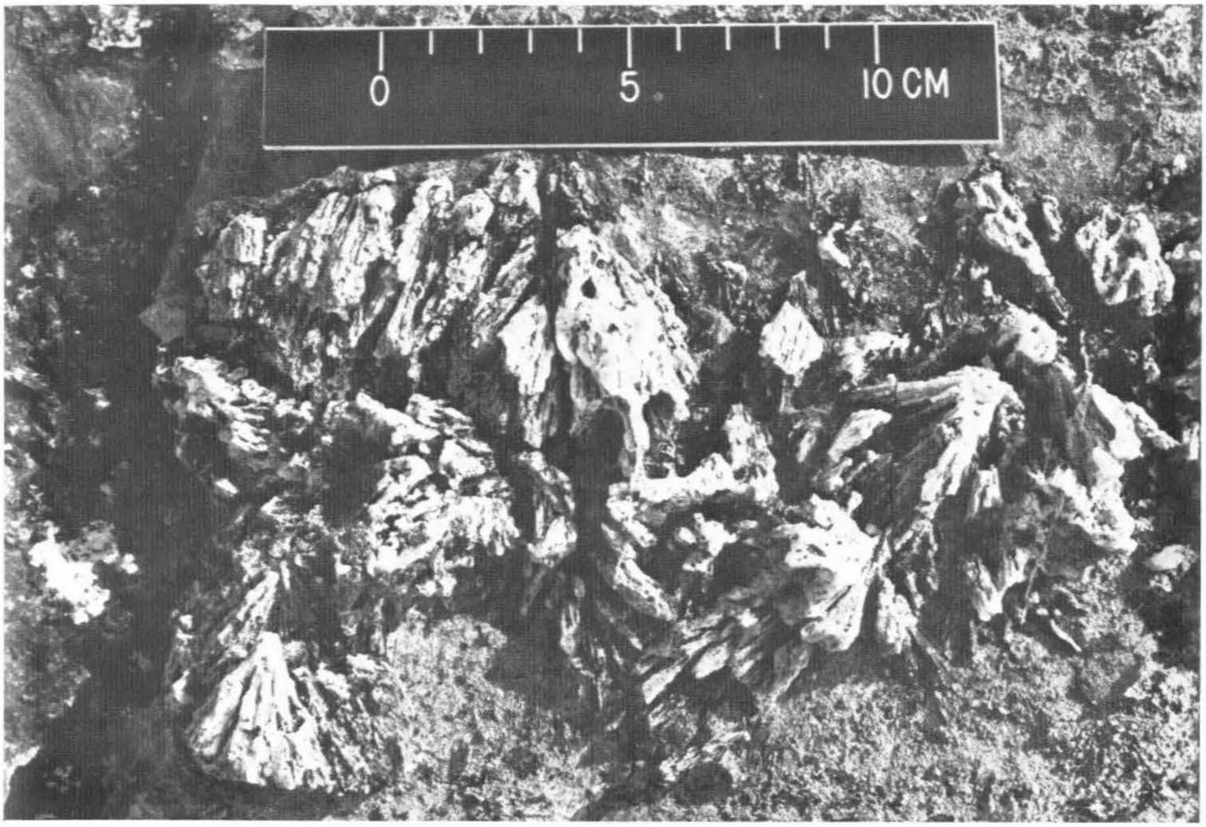

***Figure 60.2.*** *Silicified aragonite botryoids in proximal back-reef facies of Rocknest Formation. The fibres radiate stratigraphically downwards.*

The Recluse Group turbidites onlap the Rocknest continental slope, a relationship that can be seen on air photographs (NAPL No. A14234-90) of the southern closure of the Recluse Group syncline.

If it is assumed that the turbidites, which were deposited by axially-flowing currents, approximate the horizontal in an east-west section, then the difference in decompacted thickness of Recluse Group strata between the two limbs should equal the paleobathymetric relief at the end of Rocknest deposition plus the effect of regional flexure during Recluse sedimentation. By further considering the difference in Rocknest thickness across the fold, the increase in relief from the beginning to the end of Rocknest deposition can be obtained. The values for paleobathymetric relief can be converted to paleobathymetric slopes by unfolding the syncline, utilizing surface dips and down-plunge projections, to determine the original horizontal distance between the measured sections.

This was done near the south end of the syncline, where the Rocknest comprises 230 m of slope facies on the west limb and 660 m of shelf edge facies on the east limb. The difference in decompacted thickness of the Recluse Group, measured from the top of the Rocknest Formation to a marker bed in the core of the fold is 590 m, of which 430 m (the change in Rocknest thickness) can be related to constructional aggradation of the Rocknest shelf edge. Note that because the measured sections converge toward the upper marker bed and thereby minimize the difference in Recluse Group thickness, and because the method used for unfolding maximizes the original horizontal separation, the paleoslopes reported here are minimum values. The average slopes obtained are 7 degrees for the top of the Rocknest Formation and 2 degrees for its base. Regional flexure cannot have exceeded 2 degrees or a reversed Odjick paleoslope would be implied in defiance of known facies relations. Therefore, the original paleoslopes are estimated to have averaged less than 2 degrees at the end of Odjick deposition, increasing to at least 5-7 degrees at the end of Rocknest time. These values compare well with average inclinations of 1-1.5 degrees for clastic slopes and 4-10 degrees (locally steeper) for carbonate slopes on modern Atlantic-type continental margins. It should be possible to make similar measurements elsewhere along the syncline.

## Eastward Migration of Foredeep Flysch

Implicit in the interpretation of the Recluse Group as a foredeep deposit is the eastward migration of flysch deposition in front of the evolving foreland fold-thrust belt (Hoffman, 1973). Such diachroneity is difficult to prove in the absence of biostratigraphy, but by establishing a basin-wide stratigraphy for the hemipelagic "background" sediments between turbidites, evidence for eastward migration has now been obtained.

At the base of the Recluse Group throughout the externides is a westward tapering wedge of dark semipelite and craton-derived quartz siltite (Tree River Formation) with a few beds containing glauconite and/or ferruginous dolomite. The top of this unit is invariably below the flysch. The three succeeding units all intertongue westward into gritty feldspathic-lithic greywacke flysch (Asiak Formation). The lowest unit is a flat-laminated, noncalcareous pelite (Fontano Formation) that tapers and becomes increasingly graphitic and sulphidic westward. It passes upward rather sharply into a less fissile, more resistant pelite characterized by abundant calcareous concretions 2-5 cm in diameter (Kikerk Formation). This unit is overlain, above a thin transitional interval, by a remarkable unit, about 0.5 km thick, consisting of millimetre-scale limestone-argillite rhythmite (Cowles Lake Formation). These three stratigraphic units can be recognized even in sections composed dominantly of greywacke. The same sequence occurs all along the externides and in correlative sequences as far as 500 km away in Athapuscow Aulacogen (Kahochella and basinal Pethei groups: Hoffman, 1968). Basically, the sequence records stepwise increases in rate of deepwater calcium carbonate precipitation, probably due to increases in temperature or evaporation of the basin. The unit boundaries are therefore treated as approximate time planes against which the first appearance of flysch can be calibrated. As predicted in the dynamic foredeep model, the generally abrupt onset of coarse grained greywacke deposition occurs in the Fontano Formation in the west half of the fold-thrust belt, in the Kikerk Formation in the east half of the belt, and in the Cowles Lake Formation on the autochthon.

### Carousel Massif and the Nature of Basement Involvement in Asiak Fold-Thrust Belt

Carousel Massif is a unique, basement-cored, anticlinal structure within Asiak Fold-Thrust Belt (Fig. 60.1). It is here that the nature and timing of basement involvement in the deformation can be most directly ascertained. Fraser (1974) established the gross anticlinal form of the structure and recently a major décollement, located high in the lower member of the Odjick Formation, has been shown to wrap around the plunging north end of the massif (St-Onge et al., 1982, 1983). The tightly folded and thrusted panel above the décollement contrasts with the broad, simple folds of the footwall strata, which conform to the basement unconformity.

St-Onge et al. (1982) suggest that the décollement might be the sole fault for thrusts exposed to the east and our observations support this view. The décollement appears to continue down the east flank of the anticline and to merge, in the plunging syncline south of Redrock (transcurrent) Fault, with the main frontal thrust (Fig. 60.1), which places Odjick Formation quartzite above rocks as young as Cowles Lake Formation. It seems probable that the main phase of décollement folding and thrusting did not involve basement, but that the entire overthrust complex and the underlying autochthon were subsequently folded to produce Carousel anticline. This structural sequence is similar to that documented around Hepburn Batholith in the internides of the same fold-thrust belt (Hoffman et al., 1980). There, the peak of thermal metamorphism, coincident with batholith emplacement, separates an earlier phase of thrusting from a later phase of upright folding similar in scale to Carousel Massif. It is currently assumed that thrusting and later folding are two phases of the same collision event (D1 of Hoffman, 1982). The folding of Carousel Massif certainly predates the Tree River (D2) cross folding (see below) and also the D4 transcurrent faulting.

There remains the possibility of a relatively minor blind thrust having developed beneath Carousel Massif during folding. There is a fault emerging from the basement at longitude 114 degrees on Redrock Lake and apparently dying out within the Odjick Formation, but whether it is a thrust or a late transcurrent fault must be investigated further in the field. If a thrust, Carousel Massif would be only parautochthonous with respect to Slave Craton.

### Relation of Thrusting to the Takiyuak Molasse

The relation of thrusting to the Takiyuak Formation, a nonmarine, lithic-feldspathic sandstone and minor conglomerate that disconformably overlies the Cowles Lake Formation in Takijuq Basin, has been problematic. Fraser (1974) shows the main frontal thrust cutting the Cowles Lake Formation but not in contact with the Takiyuak Formation. We have recognized a smaller thrust, exposed 1-4 km east of the main frontal thrust, that extends for 17 km north of the main strand of Redrock Fault (Fig. 60.1). This thrust, also west dipping, places greywacke-rich Kikerk and Cowles Lake formations over typical red crossbedded sandstone of the Takiyuak Formation. Therefore, the possibility that the Takiyuak molasse, and its correlatives the Tochatwi Formation in Athapuscow Aulacogen (Hoffman, 1968, 1969) and the Amagok Formation in Kilohigok Basin (Campbell and Cecile, 1981), might postdate D1 thrusting has been eliminated.

### Transverse (D2) Folding of Regional Extent but Unknown Origin

The Tree River Fold Belt (Fig. 60.1) is a spectacular system of east-northeast-trending folds forming a broad synclinorium exposing Archean basement uplifts on its flanks and Kikerk Formation (Recluse Group) in its centre. So far, our mapping of these folds is limited to the south margin of Eokuk Uplift and the area of intersection of Tree River folds with the front of Asiak Fold-Thrust Belt around Kikerk Lake. In addition, a number of important features elsewhere in the orogen and beyond have come into focus as probable effects of this deformation (D2 of Hoffman, 1982), for which no obvious cause is apparent.

The fold belt is extremely well exposed due to a myriad of perpendicular diabase dykes that have been plucked out by Quaternary glaciation where they transect the Rocknest Formation, exposing hundreds of deep roadcut-like cross-sections. The folds are characteristically disharmonic, open, upright or steeply inclined, and approximately parallel. No significant thrusting has been found. Asymmetry is imposed by a penetrative cleavage that evidently formed just prior to folding. When unfolded, the cleavage dips uniformly to the north-northwest, perpendicular to subsequent folds, at an angle of less than 20 degrees. Due to flexural shear during folding, the angle between bedding and cleavage was diminished on north-dipping limbs and increased on south-dipping ones, but only in the tightest fold hinges does the characteristic pre-fold cleavage give way to a stronger axial plane cleavage. The apparent absence of thrusting and of any significant décollement within the sedimentary cover is consistent with the observed involvement of basement in the folding, which occurs on all scales from metres to kilometres. Eokuk Uplift (Fig. 60.1) is merely a major structural culmination in the Tree River Fold Belt.

The Tree River Fold Belt intersects the frontal D1 folds and thrusts around Kikerk Lake. Detailed mapping demonstrates conclusively that the D1 thrusts are folded by and therefore older than the Tree River (D2) folds, as noted earlier by Hoffman (1970). Several thrusts were first folded by D1 folds, which parallel the thrust traces, before being refolded by the transverse Tree River folds. The Tree River folds are cut by D4 transcurrent faults.

The effects of Tree River deformation are less coherent within Asiak Fold-Thrust Belt than to the east, where bedding remained relatively undisturbed until the onset of Tree River folding. Nevertheless, there are numerous 0.5 km-scale cross folds and areas of transecting cleavage that parallel the Tree River folds after rotations associated with conjugate transcurrent faulting (D4) are restored.

The major culminations and saddles in the externides as a whole, evidenced by the configuration of the basement contact and the distribution of foredeep deposits (Fig. 60.1), can now be considered as due to large scale cross folding of D2 (Tree River) age. The previously mysterious transverse arch in Crustal Block B (Hoffman and St-Onge, 1981; St-Onge, in press) of the internides may be an extension, somewhat disrupted by transcurrent faults, of the transverse arch (culmination) north of Takijuq Lake. An even higher arch at the south end of the externides exposes the Scotstoun and Acasta basement-cored anticlines in the internides southwest of Carousel Massif (St-Onge et al., 1983). These transverse D2 structures do not obviously affect the Great Bear Magmatic Zone and are tentatively assumed to be older.

Looking even farther afield, the open syncline of Kilohigok Basin strata between Contwoyto Lake and Bathurst Inlet also parallels the Tree River Fold Belt, as do the great nappes in Athapuscow Aulacogen (Hoffman et al., 1977; Hoffman, 1981). The nappes postdate the Tochatwi molasse, correlative with the Takiyuak molasse (see above), and predate the Compton Laccoliths, which are coeval with Great Bear magmatism (Bowring and Van Schmus, 1982). This is consistent with the age relations of Tree River deformation in Wopmay Orogen. The nappes, like the folds south of Eokuk Uplift, involve basement and are overturned toward Slave Craton. The cause of this extensive northwest-southeast oriented compression is not known but is probably a collision somewhere, possibly in southeastern Churchill Province (Lewry, 1981; Lewry et al., in press) or, equally possible, to the north under the Arctic Platform.

### Normal Faults Associated with D4 Transcurrent Faulting

There is a broad region centred northeast of Carousel Massif where the regional pattern of late transcurrent faults (D4), dominated by northeast-trending right-slip faults, breaks down and is replaced by a fault array of less regular trends. Specifically:

1. the right slip faults assume a more easterly orientation and commonly show evidence for dip-slip movement.
2. There is at least one domain dominated by northwest-trending left-slip faults, having up to 1 km separation.
3. There are numerous normal faults, with east-west trends and up to 250 m demonstrated slip, especially along the boundaries between right-slip and left-slip domains. Measured fault dips vary from 40 to 75 degrees, usually to the south.

Approximate contemporaneity of the faults is indicated by the fact that normal faults locally appear to merge with right lateral faults, and because there is no clear evidence that one fault set consistently offsets the other. Also, a single set of inferred principal planes of stress or strain accommodates the orientation of all fault sets. Thus the aggregate fault geometry in this region is interpreted as having arisen from a single three dimensional deformational phase involving east-west shortening, north-south extension, and (modest) vertical shortening. Although the study of general, three dimensional brittle strain is as yet in infancy, the fault orientations observed here are crudely compatible with the experimental work of Aydin and Reches (1982).

Localization of normal faulting in this region may in part be related to compatibility problems along boundaries between right-slip and left-slip domains, or to space problems where the right-slip fault system dies out toward the autochthon. However, domain boundary problems are elsewhere accommodated by faults with reverse slip (Hoffman and St-Onge, 1981), indicating some more fundamental control.

### Lead-zinc Vein Mineralization in the Rocknest Dolomite

The discovery of several minor galena-sphalerite showings during the past season indicates that the Rocknest Formation, although not conspicuously mineralized, is not barren. Northwest of Carousel Massif (65°57'N, 114°16'W), an array of about six veins, 1-40 cm wide and exposed along a strike length of 50 m, contain quartz, galena, sphalerite and minor chalcopyrite. Massive sphalerite-galena occurs in pods up to 40 cm thick and 70 cm long. The veins cut Rocknest Member 5 along the west limb of an outcrop scale D1 syncline. They strike southwest (220 degrees), with a nearly constant 50 degree northwest dip, irrespective of the bedding of the host rock, suggesting that they postdate at least some D1 structures. The mineralization clearly predates D4, because the veins are offset by numerous mesoscopic left-lateral faults.

At a second locality north of Kikerk Lake (67°28'N, 113°23'W) a non-intersecting vein set trending 350 to 005 degrees displays the same mineralogy. Individual veins are up to 2 cm wide with a 0.3 to 1.0 m spacing. They occur in Rocknest Member 10, on the footwall of Kikerk Thrust, but do not extend into the Odjick pelite on the hanging wall. It is not clear whether this observation has mechanical or temporal significance. Two other Pb-Zn indications in the same region were also found within Rocknest Member 10.

From crosscutting relations and from their trend, it is clear that the veins predate D4 transcurrent faulting. More precise dating at this time is speculative. They may be extensional fracture fillings related to D1 (buckling stresses), or perhaps D2 folding.

Although the veins are economically uninteresting in themselves, they could be indicative of more significant concentrations of cryptic, finely disseminated mineralization for which we have not searched. The occurrence in the Rocknest Formation of a distinct reefal shelf-edge facies with primary porosity, of a down-slope shale-out, and of sand sheets and organic-rich tidal-flat facies that interfinger with evaporitic (salt-casted) lagoonal muds across a shelf, 210 km in strike length and at least 160 km in restored width, that was subsequently sealed by black shale, could present some interesting situations for potential mineralization. By establishing in detail the sedimentological anatomy and dynamics of the Rocknest shelf, this project could provide the basis for some enlightened exploration.

### Future Work

For 1983, the final year scheduled for field work, study of the Rocknest Formation will concentrate firstly on the shelf edge and adjacent facies zones, and secondly on east-west changes in character of the well developed Rocknest cycles (Hoffman, 1975), especially along the Tree River Fold Belt, which appears to hold the key to understanding the dynamics of cycle generation. Priorities for structural work will be to fill in the two remaining gaps, west of Takijuq Lake and south of Kikerk Lake, in the frontal part of Asiak Fold-Thrust Belt to establish the strike lengths of individual thrusts, and to complete the work begun in the Tree River Fold Belt.

### Acknowledgments

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Tirrul's work on the structure of the externides will form the basis of a Ph.D. thesis to be submitted to University of California at Santa Barbara. Grotzinger's study of the Rocknest Formation will likewise constitute a Ph.D. thesis for submission to Virginia Tech. His work has been supported by a Geological Society of America Grant 2992-82, and a Grant-in-Aid of Research from the Scientific Research Society of Sigma Xi.

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