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DEFORMATION STYLES ALONG THE EASTERN MARGIN OF JAGO STOCK, NORTHEASTERN BROOKS RANGE, ALASKA

by

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ABSTRACT

Several different deformational styles characterize different rock units in the region surrounding the eastern margin of the Jago Stock in the northeastern Brooks Range. The behavior of the three different structural units in the field area has important implications for existing regional models of deformation. Structural Unit 1 defines the structural basement in the region and consists of the granite of the Devonian Jago stock and the Kekiktuk Conglomerate. Deformational styles within the mechanically homogeneous basement rocks differ from those of the surrounding country rocks. Depositionally overlying the stock is Structural Unit 2, which includes the Lisburne and Sadlerochit Groups. The platform carbonates of the Lisburne Group and terrigenous clastic rocks of the Sadlerochit Group have deformed separately from the stock and the Kekiktuk. Structurally overlying these are pre-Mississippian rocks which were thrust northward during the formation of the Brooks Range. These metasedimentary and metavolcanic rocks compose Structural Unit 3.

Localized areas of the granitic rocks along the upper contact of the stock are characterized by penetrative deformation, including the formation of mylonitic fabrics. The distribution of penetrative strain along the upper contact of the stock and the structural relief in the area suggest that it has deformed as a horse in a regional duplex above a floor thrust at depth and below a roof thrust along its upper contact.

In contrast to the granite and Kekiktuk, the overlying rocks of the Lisburne and Sadlerochit Groups have been deformed by outcrop-scale folds and faults. Increasing strain upsection suggests a broad strain gradient in the Lisburne and Sadlerochit. This structural unit behaves differently than the granite because a thin shaly detachment horizon at its base and its stratified character allow decoupling and formation of folds instead of penetrative structures. In contrast to elsewhere in the northeastern Brooks Range, the Kayak Shale is absent at the base of the Lisburne here and has not acted as a detachment horizon, nor allowed regional detachment folds to form in the overlying Lisburne Limestone.

The pre-Mississippian metasedimentary rocks in the field area are exposed in the hanging wall of a major south-dipping thrust fault which places them above rocks of the Lisburne Group. In addition, a sliver of granite is exposed at the sole of the thrust sheet that intrudes the pre-Mississippian rocks and presumably was sliced from the stock. The pre-Mississippian sequence shows at least three generations of structures, two of which locally have been statically recrystallized during intrusion of the granitic rocks. Closest to the stock, transposed sedimentary layering was isoclinally folded and transposed, then refolded to form small folds and crenulations, and finally contact metamorphosed. Farther from the stock, the same two generations of structures are locally overprinted by a later, probably Brookian, generation of structures, but have not been contact metamorphosed.

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Purpose

The study of the region along the eastern margin of the Jago stock was undertaken in order to investigate the relationships between three structural rock units in the area as well as to compare and contrast their deformational styles. The structural basement in the field area consists of the Devonian granite of the Jago stock and the overlying Kekiktuk Conglomerate. These units remain coupled during deformation and are characterized by penetrative structures along their contact. This sheared contact and the structural relief in the region suggest that the stock has deformed as a horse in a regional duplex. Unlike the Okpilak batholith to the west, the stock has remained internally undeformed. These differences in deformational behavior could be due to the difference in size between the plutons. Depositionally overlying the basement are the Lisburne and Sadlerochit Groups. These rocks deform as a single, second structural unit which has detached from the basement along a thin argillaceous limestone bed at its base. As a result, outcrop- to large-scale faults and folds have formed which show increasing shortening upsection. This structural style is unlike that of the basement and is unusual for these rocks in other portions of the northeastern Brooks Range. A thick thrust sheet above these rocks contains a third structural unit composed of pre-Mississippian metasedimentary and metavolcanic rocks. At the foot of the hanging wall is a sliver of granite, presumably from the stock, which shows an intrusive contact with the pre-Mississippian rocks. Contact metamorphism of the pre-Mississippian rocks has resulted in recrystallization of the structures within it, allowing the relative ages of the deformational episodes to be determined.

Future studies will include the dating of mylonitic white micas by $^{40}Ar/^{39}Ar$ isotopic techniques to determine the age of deformation of the stock. Strain analysis of the granite and strain partitioning of the Lisburne Group will be done to compare quantitatively the amount of strain in each of these structural units.

Previous Work

Sable (1977) completed a detailed study of the geology of the western Romanzof Mountains. This investigation included the petrology of the Okpilak Batholith, structural and stratigraphic surveys of the region, and a 1:63,360-scale geologic map based largely on helicopter reconnaissance and air photo interpretation. The area has also been mapped by Reiser and others (1980) at 1:250,000 scale. The interpretations in this report are based on models and interpretations of the structural geology of the area surrounding and including the Okpilak batholith by Wallace and Hanks (1990) and Hanks and Wallace (1990).

Stratigraphy

The stratigraphy in the northeastern Brooks Range can be divided into sequences that represent different stages in the tectonic and structural evolution of the area and that are bound by regional unconformities. The pre-Mississippian sequence, of Precambrian to Devonian age (Bird and Molenaar, 1987), includes low-grade metasedimentary and metavolcanic rocks, mildly deformed carbonate rocks, and three granitic plutons. These rocks form the structural basement in the most of the northeastern Brooks Range and have undergone one or more pre-Mississippian deformational events. The overlying Ellesmerian sequence is of Mississippian to Early Cretaceous age and represents a south-facing passive continental margin sequence (Bird and Molenaar, 1987). Its basal Endicott Group consists of the lower Mississippian Kekiktuk Conglomerate and Kayak Shale. The sandstones and conglomerates of the Kekiktuk generally have remained structurally coupled to the pre-Mississippian rocks during deformation beneath a regional structural detachment in the Kayak Shale (Wallace and Hanks, 1990). Overlying the Endicott Group are widespread platform carbonates of the Mississippian to Pennsylvanian Lisburne Group and various terrigenous clastic rocks of the Permian to Triassic Sadlerochit Group.

Geologic Setting

The Brooks Range fold and thrust belt trends east-west across much of western and central Alaska, but arcs to the northeast at its eastern end (Wallace and Hanks, 1990) (Fig. 1). This structural and topographic salient, which includes the field area, has undergone less shortening and was deformed later than was the remainder of the Brooks Range (Wallace and Hanks, 1990). The Devonian Jago Stock is one of three granitic plutons within the northeastern Brooks Range that intrude surrounding pre-Mississippian stratified metasedimentary rocks (Reiser et al., 1980; Dillon et al., 1987). The overlying sub-Mississippian unconformity dips eastward over the stock and is overlain by the Endicott and Lisburne Groups (Reiser et al., 1980). The Jago Stock lies in the south limb of the Aichilik River anticlinorium and in the footwall of the thrust fault defining the northern edge of the regional Mt. Greenough anticlinorium (Fig. 1). In the southern part of the field area, pre-Mississippian rocks and a thin sliver of granite in the hanging wall of this thrust overlie rocks of the Lisburne Group.

The structural geology of the region is best examined in terms of its structural stratigraphy (Fig. 2). The granite of the Jago stock and the Kekiktuk Conglomerate have deformed together and form Structural Unit 1, the structural basement in the field area. Depositionally overlying these is Structural Unit 2. This sequence includes the Lisburne and Sadlerochit Groups which have detached from the basement. Structural Unit 3 includes a sliver of granite within a thick thrust sheet of pre-Mississippian rocks which has moved northward during the formation of the Brooks Range fold and thrust belt. Each of these three litho-tectonic units will be discussed below in terms of their lithologic character and deformational styles, as well as their implications for the remainder of the northeastern Brooks Range.

Structural Geology of the Jago Stock and the Kekiktuk Formation

The Kekiktuk in the field area consists of coarse-grained sandstone with a maximum thickness of about 10 meters. It has remained structurally coupled to the stock during deformation and the two units can together be considered the structural basement in the region.

The contact between the granite and the Kekiktuk dips eastward and includes a layer of paleo-grus up to a few meters thick at the base of the Kekiktuk. The contact is marked by localized zones of penetrative strain confined to the top few meters of granite, the grus, and the very base of the sandstone. Within these zones, a strong shistosity shows very consistent orientations sub-parallel to the contact. Mylonitic fabrics are defined by anastomosing zones of secondary white micas surrounding larger, now lenticular quartz and feldspar phenocrysts. These micas probably formed during deformation and will be dated to determine the age of deformation using $^{40}Ar/^{39}Ar$ isotopic techniques. The sense of shear exhibited by these fabrics indicates northward-directed thrusting.

Structural Geology of the Overlying Lisburne and Sadlerochit Groups

The Lisburne and Sadlerochit Groups form Structural Unit 2, a thick sequence of stratified sedimentary rocks of very different structural character than the mechanically homogeneous basement. A thin detachment horizon at the base of the Lisburne allows detachment from the basement, resulting in structural styles other than penetrative deformation.

The Kayak Shale is thick in most of the region but is conspicuously missing in the field area. Instead, a thin (less than five meters thick) argillaceous shaly limestone interval marks the contact between the Kekiktuk and Lisburne, and also defines the boundary between relatively little-deformed massive rocks below and folded and faulted stratified rocks above. Although very thin, this shaly layer has acted as an efficient detachment surface, allowing ductile deformation in the cores of the minor folds where it is observed. The resulting structures include strongly north-vergent asymmetrical folds, some cored by minor thrusts, that increase in wavelength and amplitude upsection. The increase in shortening upsection suggests a broad strain gradient in the sequence due to a lack of complete detachment at the base of the Lisburne, and also possibly due to the presence of a large thrust sheet above. This deformational style is unusual for these rocks in other parts of the northeastern Brooks Range where the Kayak Shale is significantly thick to core regional detachment folds in the Lisburne.

A cliff showing a cross section through the lower Lisburne was studied in detail, with emphasis on describing the structures affecting one particular marker bed. Examples of structures in this section included asymmetrical fold pairs, fault-propagation folds, a small duplex (at a scale of 5-10 meters), and a backthrust. The cores of some folds are characterized by ductile behavior and formation of axial planar cleavage. Also noted in many structures were pressure-solution cleavage, stylolites, and evidence of bedding parallel slip. Tension fractures filled with calcite are common and some form en echelon sets.

The marker bed was measured to determine its deformed and undeformed length. From these lengths, the amount of shortening was calculated as about 18%. This value will be further constrained by adding the amount of penetrative strain determined by strain analysis of the Lisburne Limestone in this area.

Structural Geology of the Granite and Pre-Mississippian Rocks of the Upper Thrust Sheet

At the base of the regional thrust sheet in the field area a sliver of granite is exposed beneath the pre-Mississippian rocks. This sequence defines the structurally highest Structural Unit 3.

Although its upper contact is covered, the granite sliver appears to intrude the contact-metamorphosed metasedimentary rocks. The sliver is similar in composition and texture to the stock, and presumably was sliced from the it at depth to the south. If this assumption is correct, a minimum amount of displacement along the fault may be calculated.

The pre-Mississippian rocks in the thrust sheet can be distinguished by the degree to which they have been recrystallized during intrusion, presumably by the Jago Stock. Several generations of structures can be recognized in the pre-Mississippian rocks. Bedding has been isoclinally folded and transposed into dominantly axial-planar compositional banding (S1). This has been overprinted with small folds and crenulations, with an axial-planar crenulation foliation (S_2). In the lower part of the thrust sheet, both generations of structures have been statically recrystallized as a result of contact metamorphism, and therefore must be older than the Devonian age of intrusion. Joints and veins in the pre-Mississippian rocks here were probably formed during Cenozoic thrusting.

Higher in the thrust sheet and farther from the stock, the same two generations of structures are evident in phyllitic rocks that have not been contact metamorphosed. In addition, a later crenulation cleavage (S_3) locally overprints the older structures, and has been interpreted as Brookian. The S_1 and S_2 foliations in the non-recrystallized rocks show much more consistent orientations than those in the recrystallized rocks.

Preliminary Interpretations and Regional Implications

The rocks in the field area can be divided into three structural units of different lithologic character and deformational style. The structural relationships between these sequences have implications for existing models of the regional geology.

Three major deformational events led to the present geometry of the structural units in the region. First, the pre-Mississippian rocks were metamorphosed and deformed, possibly during more than one event. This deformation was followed by intrusion of the stock which resulted in the contact metamorphism and static recrystallization of the pre-Mississippian rocks. Finally, Cenozoic thrusting affected the rocks of the each structural unit during the formation of the Brooks Range.

The Jago stock shows penetrative shortening only along its upper contact in the field area. The apparent lack of deformation deeper in the granite suggests that the stock has behaved competently as a horse in a regional duplex with a floor thrust at depth and a roof thrust at its upper contact (Fig. 2). This interpretation is consistent with a model proposed for the deformation of most other pre-Mississippian rocks in the northeastern Brooks Range (Wallace and Hanks, 1990) but differs from the structural behavior described for the Okpilak batholith which appears entirely penetratively deformed (Hanks and Wallace, 1990). It is possible that the much larger batholith was unable to deform as a single horse as was the stock and hence developed penetrative structures throughout.

Because the Kayak Shale is absent in the field area, the cover rocks have only minimally detached from the granite of the Jago stock. The thin layer of argillaceous limestone at the base of the Lisburne Limestone and their layered character allowed the cover rocks to deform independently of the competent and mechanically homogeneous basement. The detachment layer was not sufficient, however, to allow the regional thrust fault to flatten out as it would have if the Kayak Shale had been present. Instead, the fault continued upsection through the Lisburne Limestone. The detachment layer was also inadequate to form large detachment folds as does the Kayak Shale in other parts of the northeastern Brooks Range.

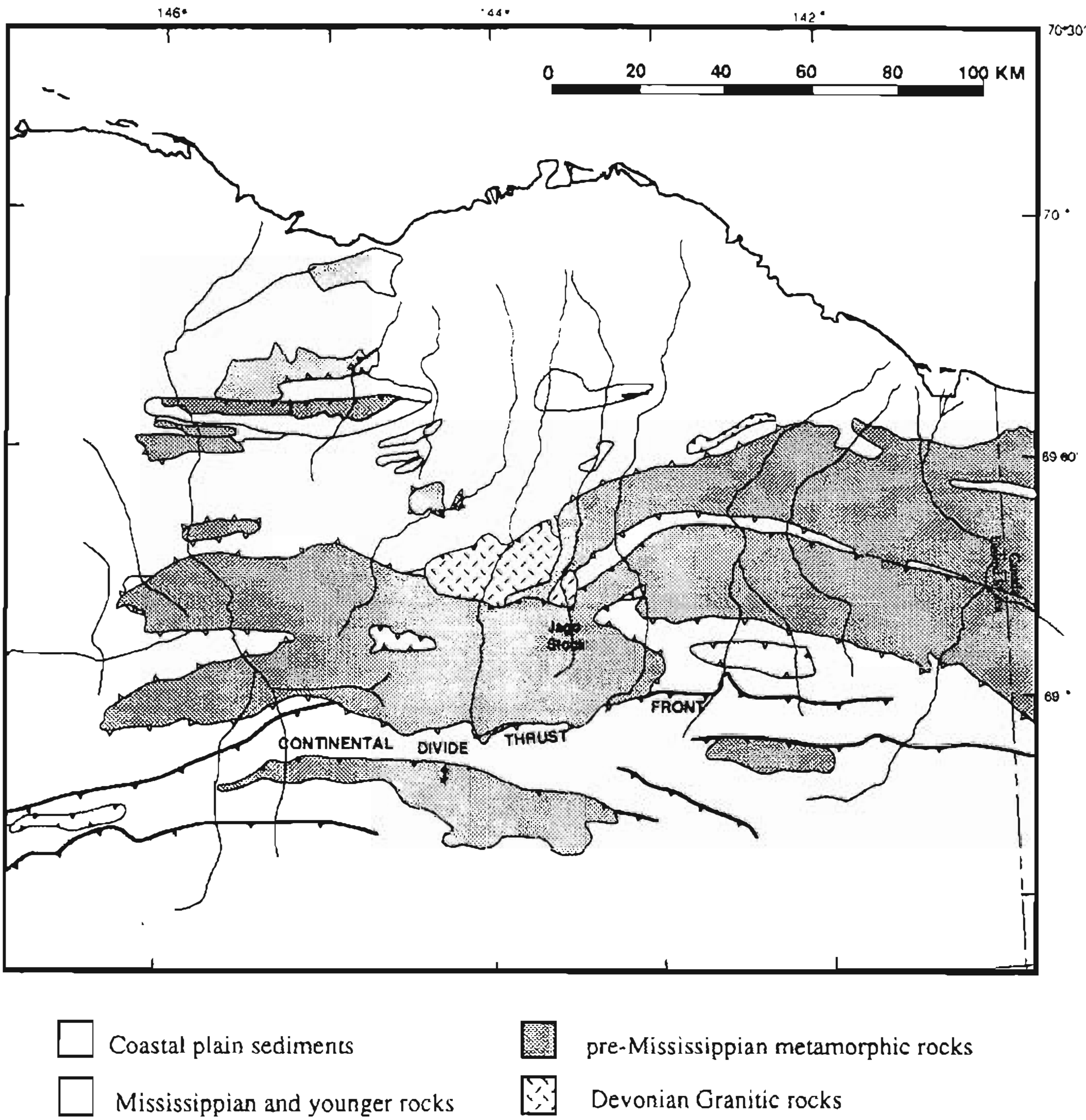

Figure 1. Geologic map of the northeastern Brooks Range showing structural stratigraphy and location of Jago stock. Modified from Hanks and Wallace (1990).

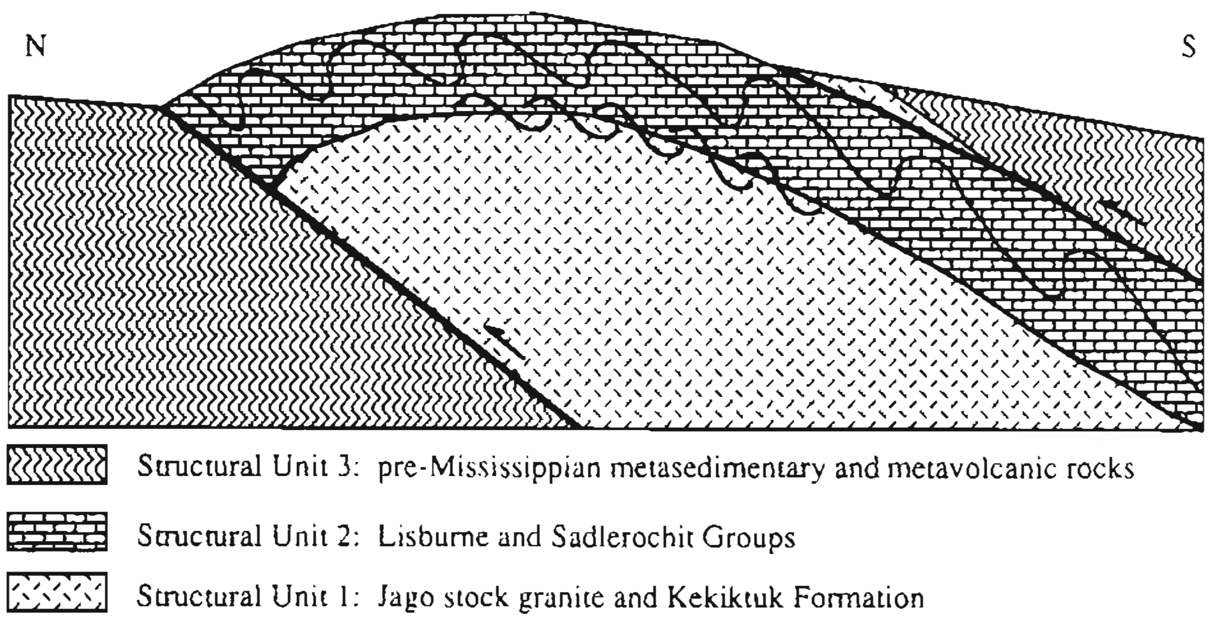

Figure 2. Schematic cross section through the Jago stock region showing structural stratigraphy and essential structural relationships.

APPENDIX: MAP UNIT DESCRIPTIONS

TRPs - Triassic-Permian Sadlerochit Group
Red-weathering grey siltstone

uPMl-Pennsylvanian-Mississippian Upper Lisburne Limestone
Coarse-grained bioclastic limestone with crinoids. Black and white nodular chert common. Oolitic limestone with siliciclastic grains.

lPMl-Pennsylvanian-Mississippian Lower Lisburne Limestone
White-weathering dark grey to black fine grained limestone. Less commonly faintly laminated; interbedded fine-grained and coarse-grained limestone. Rarely iron-stained coarse-grained bioclastic limestone with crinoids. Minor chert nodules.

Mk - Lower Mississippian Kekiktuk Formation of Endicott Group
Blue-grey coarse-grained quartz sandstone with moderately well-sorted, subangular grains. Subordinate blue-black fine-grained quartz sandstone.

Dgr- Devonian Granite of the Jago Stock
Blue-grey granite with essential quartz, biotite, zoned feldspar megacrysts, plagioclase, muscovite. Pyrite and hornblende common.

€ss1-Pre-Mississippian Metasedimentary Rocks (1)
Contact metamorphosed metasandstones and metacarbonates. Grey and white to orange compositional layering common.

€ss2-Pre-Mississippian Metasedimentary Rocks (2)
Light to dark grey and brown fine- to medium-grained sandstone and phyllite. Subordinate coarse-grained sandstone with chert nodules.

€p - Pre-Mississippian Metasedimentary Rocks (3)
Green, maroon, and black phyllite.

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