

DEEP CRUSTAL DEFORMATION BY SHEATH FOLDING IN  
THE ADIRONDACK MTS., U.S.A.

J.M. McLelland, Colgate University

As described by McLelland and Isachsen<sup>1</sup>, the southern half of the Adirondacks are underlain by major isoclinal ( $F_1$ ) and open-upright ( $F_2$ ) folds whose axes are parallel, trend approx. E-W, and plunge gently about the horizontal. These large structures (50-100 km along strike) are themselves folded by open upright folds trending NNE ( $F_3$ ). McLelland<sup>2</sup> pointed out that elongation lineations in these rocks are parallel to X of the finite strain ellipsoid developed during progressive rotational strain. These linear elements are most spectacular in ribbon gneisses consisting of quartz and feldspar ribbons up to 60 cm long, 1 cm wide, and 1-2 mm in thickness. The ribbons can be shown to evolve from progressively sheared feldspar megacrysts as well as aggregates of quartz grains, both indigenous to inequigranular granitic plutonites.

The parallelism between  $F_1$  and  $F_2$  fold axes and elongation lineations led McLelland<sup>2</sup> to hypothesize that progressive rotational strain, with a west-directed tectonic transport, rotated earlier  $F_1$ -folds into parallelism with the evolving elongation lineation. Rotation is accomplished by ductile, passive flow of  $F_1$ -axes into extremely arcuate, E-W hinges, i.e., sheath folds.  $F_2$  folds represent either response to convergence in the ductile flow field or are the crests and troughs of large sheath folds with which they are contemporaneous.

In order to test these hypotheses a number of large folds were mapped in the eastern Adirondacks. The largest of these (McLelland and Isachsen<sup>1</sup>) lies just south of the Marcy anorthosite massif and is referred to as the  $F_2$ , Pharoah Mt. anticline. This anticline has a wavelength of ~ 20 km and plunges gently to the east at its eastern end. The charnockites coring the anticline may be followed for at least 50 km to the east and reappear in the Ticonderoga dome ~ 10 km to the east. On the flanks of the anticline are distinctive marbles of the Paradox Lake Formation whose contact with the charnockites gives clear expression to the anticline. As these marbles are followed north or south from the anticlinal hinge they can be traced around vertical isoclinal ( $F_1$ ) fold hinges that occur on both flanks of the  $F_2$  anticline. The only way for this geometry to be consistent is if the Pharoah Mt. anticline is a flattened sheath fold with horizontal hinges that are isoclinal.

Other evidence supporting the existence of sheath folds in the Adirondacks is the presence, on a map scale, of synforms whose limbs pass through the vertical and into antiforms. This type of outcrop pattern is best explained by intersecting a horizontal plane with the double curvature of sheath folds.

It is proposed that sheath folding is a common response of hot, ductile rocks to rotational strain at deep crustal levels. At shallower levels the crust responds to the same forces by developing thrust faults such as those mapped by McLelland and Isachsen<sup>1</sup> in the eastern Adirondacks. The development of sheath folds is probably commonplace within the high grade cores of major mobile belts. The presence of such structures should be suspected whenever well developed elongation lineations parallel early fold axes, especially when these are isoclinal. Of paramount importance are tectonic interpretations related to sheath folding, because, unless recognized as parts of sheaths, the isoclinal fold hinges may be misinterpreted as perpendicular to the long axis (X) of the finite strain ellipsoid when, actually, they are parallel to it. Thus, the recognition of sheath folds in the Adirondacks reconciles the E-W orientation of fold axes with an E-W elongation lineation. These folds appear to have formed during, or shortly prior to, peak granulite facies metamorphism at ~ 1050 Ma<sup>3</sup>. They fold an earlier high grade (garnet-sillimanite-K-feldspar) foliation which is believed to pre-date ~1300 Ma<sup>3</sup> tonalitic gneiss. Orthogneisses emplaced at 1160-1130 Ma<sup>3</sup> are clearly effected by the sheath folding. The Sacandaga Fm. that envelopes the Piseco anticline of the southern Adirondacks is believed to be a mylonitized migmatite envelope around the 1150 Ma<sup>3</sup> granitic gneiss coring the anticline. The mylonitization formed during sheath folding and ribbon lineation formation along the anticline.

1. McLelland, J. and Isachsen, Y. (1986) The Grenville Province. Geol. Assoc. Can. Sp. Pap 31: 75-95.

2. McLelland, J. (1984) J. Struc. Geol. 6: 147-157.

3. Chiarenzelli, J., McLelland, J., Bickford, M., Isachsen, Y., Whitney, P. (1987) Geol. Soc. Am. Abstracts with Programs 19: in press.