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Introduction

The polymetamorphic, complexly folded rocks of this part of the Carrabassett valley are instructive from the points of view of linking stratigraphies that are interrupted along strike by large plutonic bodies, and of witnessing a regional development of contact metamorphic assemblages produced in two recognizable dynamothermal events. On the one hand, stratigraphic and structural observations gathered in this and adjacent areas flanking batholithic plutons have each reinforced the other to provide a stratigraphic synthesis which can now be used to relate some of the Siluro-Devonian formations in the Merrimack synclinorium across a paleotectonic hinge to formations of similar age in the Moose River synclinorium (see introductory article, this guidebook). On the other hand, the areal distribution and textural relationships of metamorphic mineral assemblages in the valley tell much about the concurrence of thermal events with the crowding and rearrangement of simpler regional structures during the forcible emplacement of the Sugarloaf gabbroic massif to the west, and the Lexington granitic batholith to the east.

The setting for this trip is thus one of a complexly folded metasedimentary sequence straddling the north-south trend of the Carrabassett River. The terrain in which this sequence is exposed is referred to here as the "Carrabassett corridor". The igneous rocks that form the structural walls of the corridor can be considered as the opposing jaws of a tectonic vice on which can be blamed most of the kinematic happenings preserved in the rocks to be witnessed during the trip.

Acknowledgments

The Maine Geological Survey supported the field mapping. I am indebted to Robert G. Doyle for his continued support, and to geologists of the U.S. Geological Survey, particularly E.L. Boudette, R.H. Moench, and A. Griscom for discussions in the early stages of mapping that allowed me to benefit from their work already in progress in adjoining quadrangles. A study of late-stage retrogressive metamorphism and metasomatism in the rocks at stop 6 was carried out by

(Stratton)

45°00′
70°15′

(Kingfield)

10′

Mile 0 .5 1
Km 0 .5 1

Fig. 1. Structure and stratigraphy of Carrabassett valley region, Little Bigelow Mountain quadrangle

Figure 1 EXPLANATION

Igneous Rocks

Post-lower Devonian

Lexington Batholith

Dqme c.g. equigranular quartz monzonite

Dqmp q.m. porphyry (roof and wall facies)

Dgd granodiorite and diorite (ornament for batholith margins only)

Huston Flats granite-diorite stock

Late Acadian

Sugarloaf gabbroic massif

medium- to coarse-grained gabbro, gabbro pegmatite, norite, and gabbroic anorthosite.

Layered in part (ornament for massif margins only)

[Dikes and sills of gabbro, diabase, and garnetiferous aplite not shown]

Structural & Logistic Symbols

Contact
Dashed where inferred or concealed;
dotted where gradational

Inferred fault

Anticline, showing direction of plunge
Queried where inferred

Syncline
normal and overturned

5 ● Outcrop areas described in road log for trip A-2

Metasedimentary Rocks

lower Devonian

Ds Seboomook formation

Upper member: cyclically graded-bedded metagraywacke and metashale (andalusite-cordierite schist or retrograde equivalents and sillimanite granofels in Carrabassett valley and Bigelow Range). Graded sets 5 cm to a meter thick; 10-15 cm common. Pelitic portions gray to dark gray, graywacke portions gray to light gray, on fresh surfaces.

Dsq Schist and graywacke lower member: prominantly graded bedded in Carrabassett valley; lenticular and sheared within 2500 meters of Lexington batholith contact. Staurolite + garnet (chiefly as relicts) at, and SW of Rt. 16 - 27. Aluminous layers andalusite-bearing throughout most of area. Graded sets 5 to 30 cm thick.

lower Devonian (?)

Dcc Carrabassett Formation (informal designation)

Sulfidic calc-silicate and schist member; proportion of calc-silicate to pelitic schist varies widely. Consistently sulfide-bearing. Calc-silicate rocks thin- to medium- layered. Associated non-porphyroblastic muscovite-biotite-plagioclase schist. Minor thin quartzite layers.

Dcq Biotitic metaquartzite member. Variously feldspathic; thickly bedded or massive. Minor thick zones of massive gray schist. Metaquartzite dark gray where fresh; weathers to medium gray.

Stratigraphic position varies from uppermost part of Dcms to Dcc. Forms thick, laterally discontinuous lenses.

Dcqs Thinly layered andalusite-cordierite schist and non-porphyroblastic quartz-rich schist. Rare staurolite relicts in sub-porphyroblastic schist layers. Poorly developed graded bedding.

Dcms 'Massive' andalusite schist member; relict bedding very indistinct, or lacking; quartz-rich segragation-laminae (paper-thin to 2 mm thick, 3 to 6 cm long) developed along axial plane cleavage. Sulfide (as sulfide-quartz lenticles) very rare. Restricted sections, up to 50 feet thick, of graded-bedded metapelite and metagraywacke.

Silurian or Devonian (?)

DSu Cordierite-rich, hypersthene-spinel rafts or roof pendants in Sugarloaf massif.

Silurian (?)

Sp Perry Mountain (?) formation

Thin- to medium- graded-bedded muscovite-rich sillimanite-almandite granofels.

P.T. Lyttle, then an undergraduate at Syracuse. To the residents and land owners of the Carrabassett valley I express my thanks for their cooperation.

"Margaret and Frike"

As man becomes aware of his perpetrations upon nature, probably farthest from mind is the despoiling of rock outcrops with paint, let alone hammering. Some of the most spectacular outcrops, geologically and scenically, in the Carrabassett valley are extensively marred from the use of pressurized paint spray-cans. The 'half-life' of sprayed enamel is not yet measurable after four years' exposure. Despite this condition of some of the outcrops, I ask participants to refrain from hammering the most instructive (often weathered) surfaces.

Stratigraphy and Structure

The stratigraphic and structural synthesis in the Carrabassett corridor, as in many metamorphic terrains, has consisted of a cyclic integration of local structural geometries and lithologic successions. Each has led to a clearer understanding of the other, often from widely separated parts of the area. The relative inaccessibility of many key outcrops with regard to the time available for this trip has of necessity been the deciding factor in choosing selected outcrop illustrations of the principal problems, and there to share with participants the techniques and reasoning employed in the attempt to solve them. With such prospects of minor incisions to expose the anatomy of the corridor, its general structure and evolutionary history are herewith 'unfolded'.

Upon entering the Carrabassett valley at Kingfield, the structure of the Siluro-Devonian units deviates little from the regional northeasterly trend (see Raabe, this volume). Stratigraphic relations in rocks to the north in the Carrabassett corridor (Little Bigelow Mountain quadrangle), are based on the continuity of the section here and to the east of the Lexington batholith (fig. 1).

The plunge of major fold axes (not lineations) from the southern quadrangle boundary to Little Poplar Mountain is generally northeasterly. Together with top-facing depositional criteria in rocks near unit boundaries, these observations lead to the interpretation of progressively younger strata encountered in following the plunge of folds north to the vicinity of Little Poplar Mountain. These strata comprise units which are not recognized, or not separately defined as units, to the south. Brief mention of the succession is necessary here.

At the northern boundary of the Madrid Formation local faulting has disrupted the contact with overlying pelite. In eastern Little Bigelow Mountain quadrangle, however, the contact is gradational by way of interbedding across ~ 100 feet of section, and top-facing criteria (cross-bedding in the Madrid, and graded-bedding in the overlying pelitic sequence) have been recognized very close to the contact where intervening minor folds are believed absent.

The immediately overlying pelite and associated local units in the Carrabassett valley are to be formally designated in a forthcoming publication as the Carrabassett Formation; it consists, in ascending order, of "massive" pelite, thinly interbedded pelite and quartz-rich pelite, thick, discontinuous lenses of massive or thickly bedded quartzite and minor thick zones of pelite, topped by thinly bedded, characteristically sulfidic aluminous calc-silicate and pelite which is quite variable in these lithic proportions along and across strike.

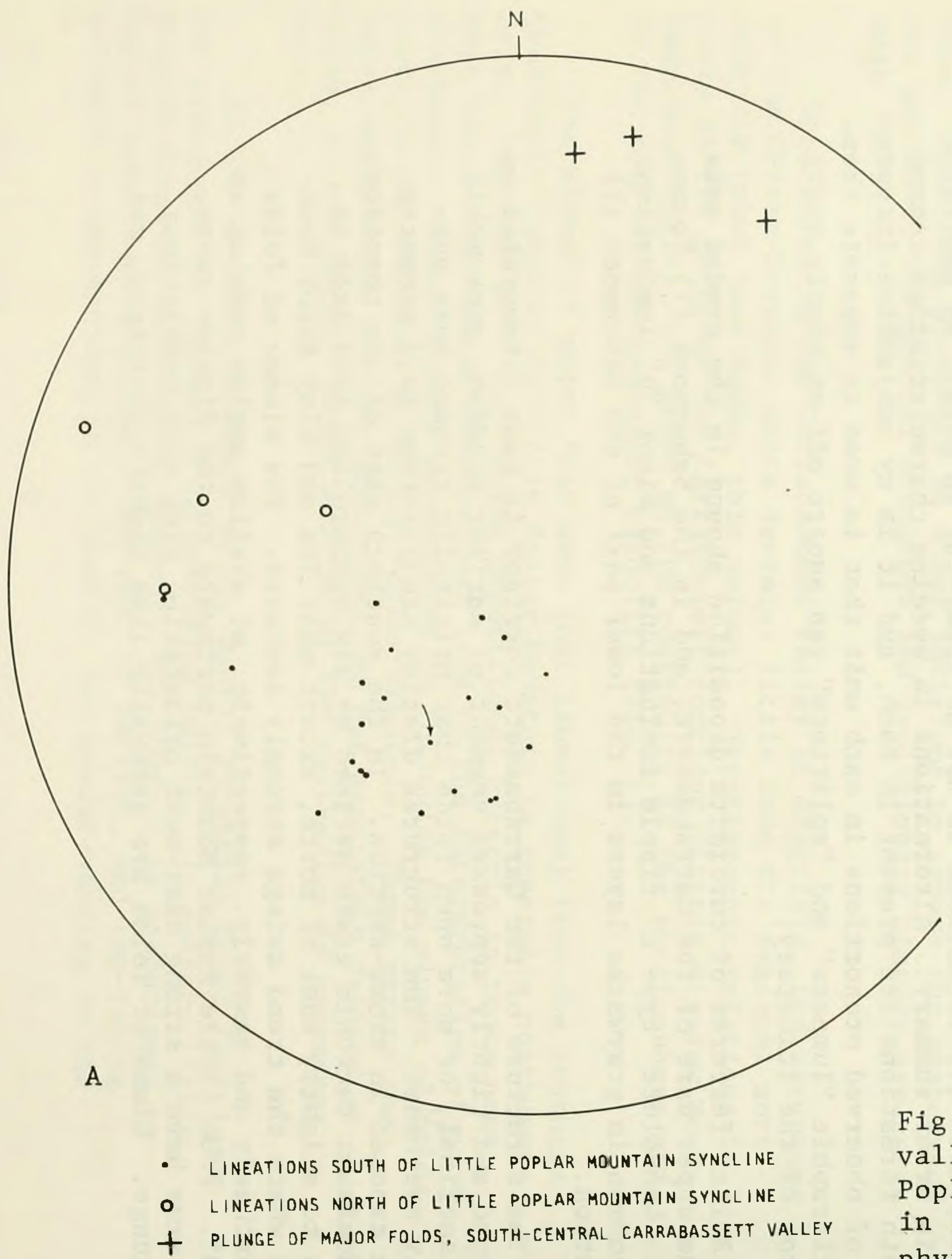
The massive quartzite member appears to be similar, in stratigraphic position and in sedimentary disposition to surrounding units, to the Whisky quartzite of the Moose River synclinorium as described by Boucot (1969).

The highest stratigraphic unit of the valley (and indeed, of the entire Little Bigelow Mountain quadrangle) into which the Carrabassett Formation grades abruptly, is composed of graded bedded metagraywacke and metapelitic rock, and quartzite. This unit is correlated with the Seboomook Formation of the Moose River synclinorium as defined by Boucot (1969). The proportion of quartzite and metagraywacke to metapelite decreases from the lower part of the formation to its highest exposed part. We will see the lower part of the formation on this trip.

The distinctions made between the pelitic parts of the Carrabassett and Seboomook (?) formations is not as clear-cut in detail as portrayed in this brief summary. Alternations in bedding characteristics commom to both formations are present in each, and it is my subjective integration of observed proportions in each unit that is used to separate them. Stratigraphic "lumpers" and "splitters" can square off on nearly every outcrop of the itinerary.

Relict features of turbidite deposition abound in the graded sets of the upper part of the Carrabassett, and in the Seboomook (?) Formation. Convolute "type c" ripple laminations and minor "b" laminations are common in graywacke layers in the lower part of the Seboomook (?) Formation.

The structure of the Carrabassett corridor is best interpreted as a warped and tightly appressed segment of earlier Acadian, presumably sub-isoclinal, or more open folds that originally trended more uniformly northeast. The structures display similar-type fold geometry where exposed in cross-section. In the southern part of the corridor the dominant tectonic grain defined by six subparallel fold axes is north to slightly east of north, except near Ira and Clay Brook Mountains where the trend swings strongly eastward. The plunge of folds is northerly and easterly, respectively, at shallow angles ranging up to 20°. From Little Poplar Mountain northward to the Bigelow range, fold axes have a strong east-west orientation with mild undulations of plunge. Limbs of folds are generally less tightly appressed, and



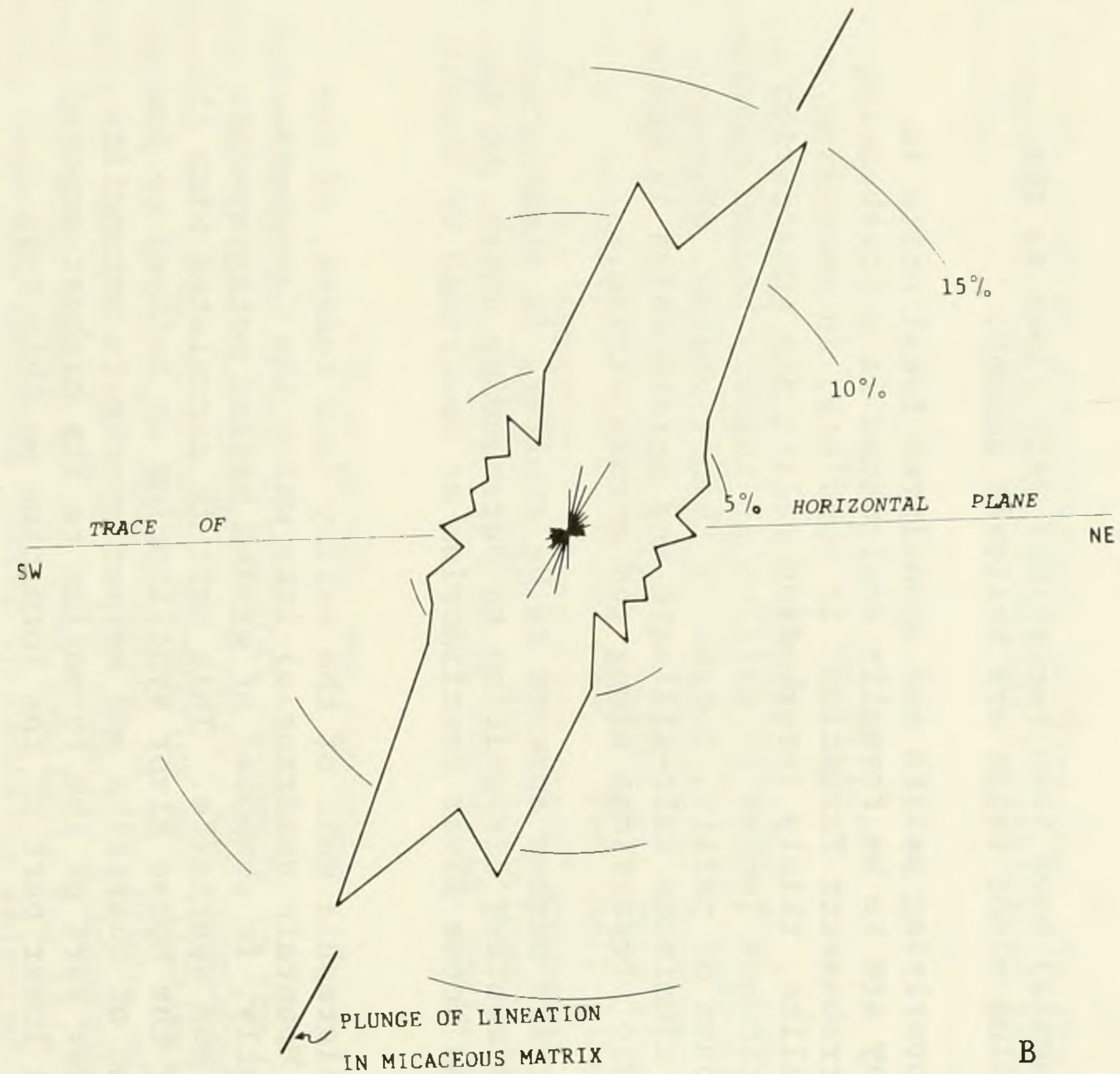


Fig. 2. A: Lineations and fold axes in Carrabassett valley, from southern quadrangle boundary north to Poplar Stream. Arrow points to lineation-fabric study in (B). B: Preferred orientation of andalusite porphyroblasts in lower part of Seboomook (?) Formation, Carrabassett valley (stop 6). Plane of diagram represents vertical foliation surface. Bar lengths at center indicate preferred orientations of boudinaged crystals.

fold amplitudes in the calc-silicate member of the Carrabasset Formation, and in the Seboomook (?) Formation are much decreased around the lower flanks of the Bigelow range.

The locus of structural change at Little Poplar Mountain also marks the center of a modified triangular syncline which is flanked by two gabbro bodies and by the westernmost lobe of the Lexington Quartz Monzonite.

Between Kingfield and the Little Poplar Mountain syncline, older rock units are exposed where the corridor is widest; correspondingly where the corridor is narrowest, younger units are exposed. It thus appears that the greatest vertical adjustment in response to late- and post-Acadian intrusion tectonics took place by flattening (crowding) between the intrusive boundaries where they form the most salient parts of the tectonic vice. Flattening was preceded or accompanied by subsidence, particularly during the intrusion of the Lexington batholith. Subsidence also was greatest where the lobes of bordering intrusions are more closely juxtaposed. Flattening and subsidence in the metasedimentary cover took place in response to the domical rise of the quartz monzonite while the nearby gabbroic bodies remained as semi-rigid buttresses. The orientation of least-principal stress is believed to have been steeply southwesterly-plunging at this stage of deformation in the south half of the corridor. Widely distributed occurrences of aligned, boudinaged andalusite pseudomorphs (see structural data, fig. 2) support this interpretation. Local modifications of stress-fields will be suggested at most of the stops.

The significance of lineation in the Carrabassett valley is intimately related to the metamorphic history, and is discussed below.

Metamorphism

The rocks of the corridor were metamorphosed in two thermal events of presumed late Acadian age. The first was associated with the emplacement of the Sugarloaf gabbroic massif and other mafic bodies of the area, was more intense, and affected a larger volume of rock. The second attended the emplacement and cooling of the Lexington batholith. Dikes and apophyses of granitic rocks cut the gabbros in numerous localities in the Little Bigelow Mountain quadrangle, and attest to relative ages.

Metamorphic relations in the corridor clearly indicate that the mafic intrusions caused much more intense, widespread metamorphism than did the granitic. The association of low pressure - intermediate facies progressions (fig. 4) with strongly developed tectonite fabrics bears much similarity to the Buchan area of the eastern Scottish highlands (Read, 1935) and to its facies series of metamorphism (Read, 1952; Craig, 1965). Similarities with the metamorphic aureoles of western Ireland are also to be noted below.

It has not been possible to determine to what extent early

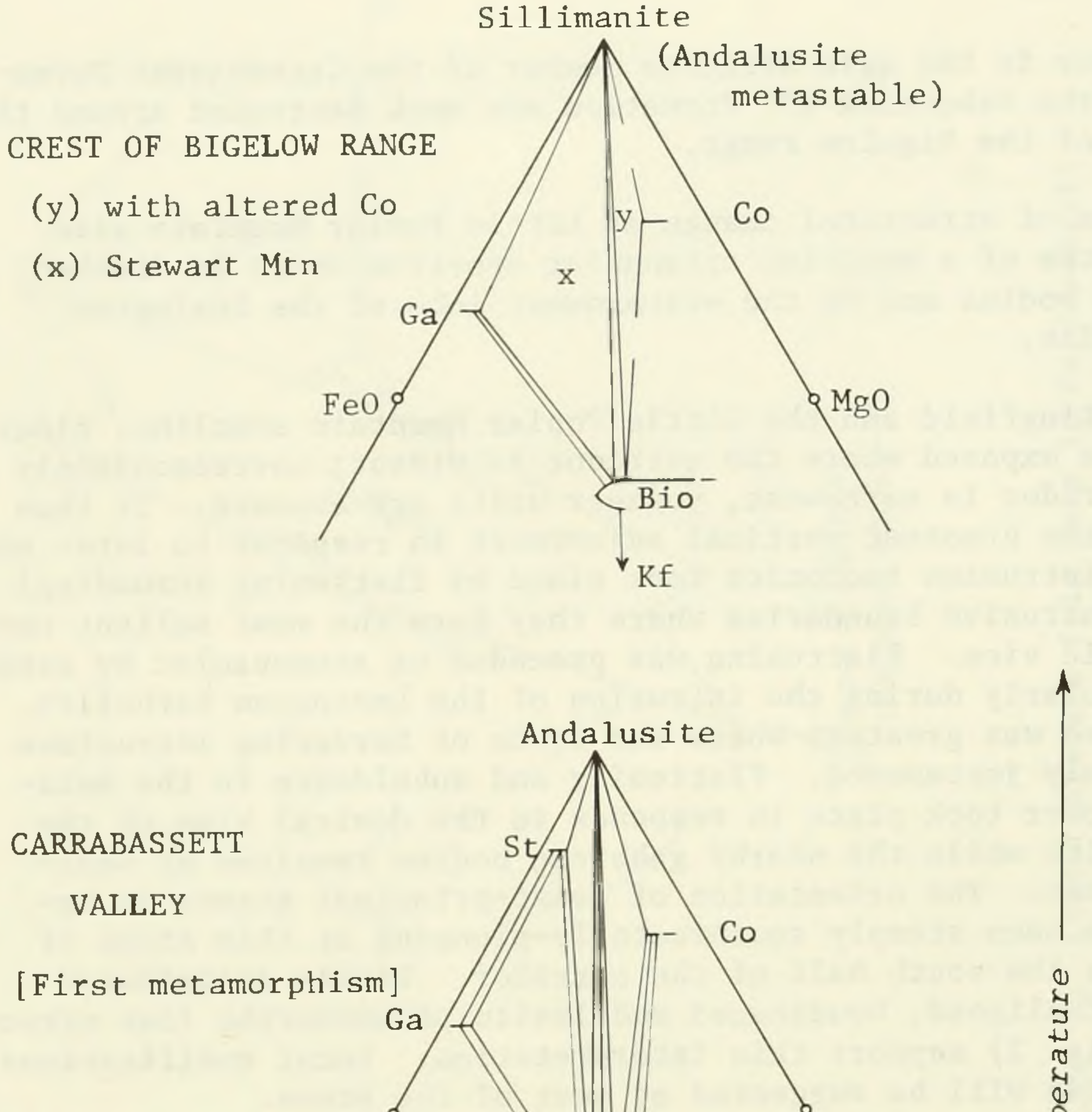


Fig. 3. Sequence of mineral assemblages in Carrabassett valley area from Kingfield township north to Bigelow Range. Diagrammatic; AFM projections from muscovite. Not shown is high-T, SiO_2-deficient assemblage cordierite-biotite-green spinel-orthopyroxene common in pelitic xenoliths in Sugarloaf massif.

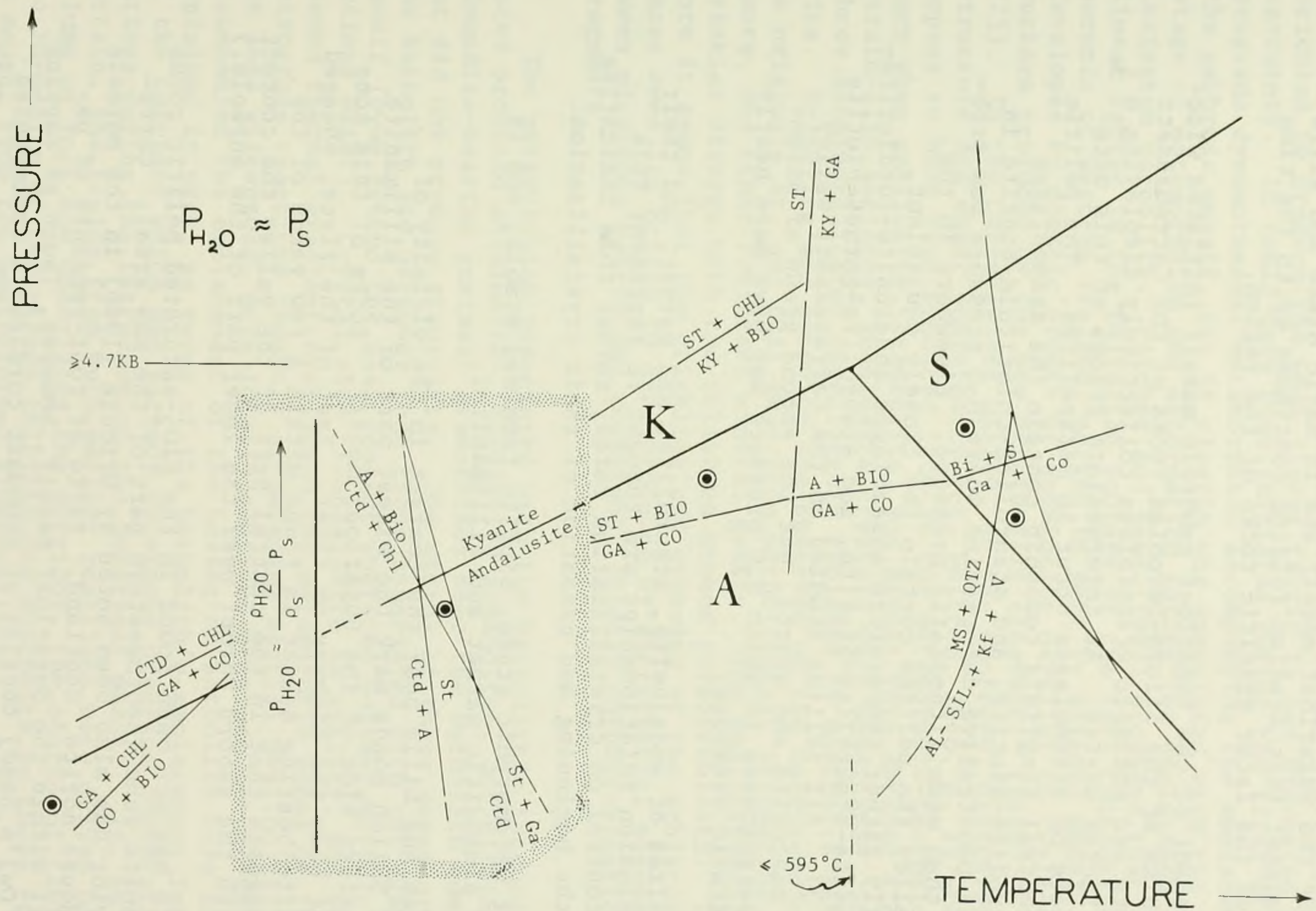


Fig. 4. Metamorphic zonal series for west half of Little Bigelow Mountain quadrangle and adjacent areas. Inset shows relative P_S-T location for chloritoid-staurolite-andalusite phyllite in west-central Kingfield township. Approximate locations and slopes of reaction boundaries from Albee (1965); coordinates of triple-point in Al_2SiO_5 system from Richardson and others (1969). Relative position of high-pressure limit for assemblage garnet + cordierite (+ biotite) modified from Hirschberg and Winkler (1968, fig. 1).

Acadian deformation had proceeded when the gabbroic magmas of the Sugarloaf massif and Flagstaff igneous complex intruded to the present level. Simple analogy with slate terrains to the northeast would imply that isoclinal folding had already been accomplished. However, shearing, protoclasis, and recrystallization of gabbroic rocks in marginal parts of the Sugarloaf massif and in mafic dikes and sills of the region suggest that Acadian folding continued up to the time of emplacement of the later granitic rocks of the region.

The emplacement of the Sugarloaf gabbroic massif initiated widespread metamorphism of the Siluro-Devonian rocks of the Carrabassett valley to schists and gneissic granofelses collectively displaying a Buchan type of facies series. At intermediate grades of this metamorphism, two sets of assemblages occur in metapelites. The pelitic rocks in west central Kingfield township contain the assemblages andalusite-staurolite-biotite, and staurolite-chloritoid-biotite in a zone of strong penetrative deformation where H_2O pressure was probably much less than mean lithostatic pressure. Elsewhere in the Carrabassett valley the pelites contain the closely equivalent, probably slightly higher temperature assemblages andalusite-cordierite-biotite, andalusite-staurolite-biotite, and staurolite-garnet-biotite (compare, fig. 3). All pelites studied in the Carrabassett valley contain excess muscovite and quartz, but the second group of assemblages denote parageneses in which H_2O pressure may have more nearly equalled lithostatic pressure.

Relative sizes of andalusite, staurolite, and garnet, and their mutual host-inclusion relationships are thought to represent bulk compositional control on crystallization rates, rather than indicating the timing of the beginning and cessation of their crystallization.

At highest metamorphic grade, biotite remained stable, and is accompanied by almanditic garnet and sillimanite.

(Low ridges and hills near the contact in the vicinity of Grindstone and Shiloh ponds mark the widest part of the sillimanite zone on the eastern side of the Sugarloaf massif. Rocks of this zone do not crop out near the highway or river. East of the river, sheared relict andalusite-bearing schist is found within a few yards of the gabbro, and suggests that in the central part of the valley the contact is faulted, with the gabbro thrust over the inner part of the aureole.)

Cordierite has not been found in the SiO_2-saturated pelitic rocks of the sillimanite zone (southwestern part of the map area). Corresponding behavior has also been noted by Gribble (1966) in the aureole of the Haddo House norite, Scotland. Rafts of roof-pendants of pelitic rock well within the Sugarloaf massif, however, (such as capping the summit of Owl's Head) consist of abundant cordierite accompanied by green (hercynite-rich?) spinel, hypersthene, and plagioclase. This suggests that the ubiquitous silica-oversaturated pelites were desilicated at the upper contact, and were engulfed by the gabbroic intrusion. Leake and Skirrow (1960) also proposed desilication for quartzose pelites in contact with mafic and ultramafic rocks in western Ireland.

The andalusite produced during this first stage of metamorphism in the Carrabassett valley is chiastolitic, is of large porphyroblastic dimensions, and exhibits a weak, preferred orientation within the plane of schistosity.

The stage during which the andalusite became preferentially oriented to produce the weak linear fabric is not bracketed with certainty. It could have been initiated during the first stage of prograde dynamothermal metamorphism accompanying the emplacement of the gabbroic massif, but it clearly was associated with the second stage of metamorphism and deformation during the emplacement of the Lexington batholith. Pitcher and Read (1963) proposed that a weak linear fabric in the Dalradian schists of the late Caledonian Thorr aureole of western Ireland, marked in part by aligned andalusites, developed by mimetic growth of andalusite parallel to "well-marked puckers produced by the new strain-slip cleavage;" (ibid., p. 268; 273). In the Carrabassett valley, on the contrary, Gleitbrett structure and shear schistosity (cf. Whitten, 1966, p. 137-140) appear to have been produced late in the metamorphic-tectonic history when andalusite, staurolite, and garnet were abraded along strain-slip surfaces, andalusite crystals were boudinaged, and all three aluminosilicates were largely replaced by muscovite and chlorite. Crinkling and grooving are observed on the macroscopic scale to originate at, and tail away from porphyroblast idiomorphs, fragments, and other resistant mineral grains. The smallest-scale crinkles diverge with the foliation around porphyroblasts. Therefore it seems that the crinkling and grooving of the schistosity surfaces owes its origin to drag produced by differential movement between micaceous matrix and resistant, chiefly porphyroblastic mineral fragments.

The metamorphism associated with the batholithic intrusion produced prograde andalusite-, cordierite-almandite-, and sillimanite-almandite-bearing gneissic granofelses near the batholith contacts, but did not produce staurolite. The widths of these zones around the batholith are narrower than those associated with the gabbroic massif (even around the east contact where no polymetamorphic complications exist). Crystal size of andalusite is smaller, and where the second thermal gradient overlapped the metamorphic zones of the first, retrograde reactions commonly accompanied partial phyllonitization. The less widespread, more locally confined prograde metamorphism that accompanied the emplacement of the Lexington batholith here can be explained in part, in terms of the batholith's emplacement into rocks of the corridor which had already undergone prograde dehydration reactions during the intrusion of the Sugarloaf massif. If, as seems certain, the fluids from such earlier reactions were driven out of the volume of rock now underlying the corridor, the source of fluids for the formation of retrograde chlorite and muscovite in these rocks must be sought from the newly-formed aluminosilicate-, garnet, and cordierite-bearing gneissic granofelses adjacent to the batholith, and perhaps from water expelled from crystallization of hydrous granitic magma. Evidence for and against this latter possibility will be reviewed during the trip.

Chiastolite porphyroblasts produced in stage 1 were rotated, boudinaged, abraded, and altered to pseudomorphs consisting mainly of fine-grained white mica. Staurolite, cordierite, and garnet were largely altered to chlorite-white mica pseudomorphs.[2] The planar fabric diagram (fig. 2) indicates the degree of parallelism of andalusite pseudomorph alignment and boudinage with the locally pervasive "crinkle" lineation in the schistose matrix. The degree of rotation and destruction of porphyroblasts corresponds to the intensity of the southwesterly-plunging lineation.

The southwesterly-plunging lineation is widespread in the pelitic schists of the Carrabassett corridor, and is perhaps its most undeviating structural feature. It does not bear a fixed relationship to plunge of major fold axes, as we will observe, yet it approximates a tectonic a lineation at many localities in the south half of the corridor where major folds plunge to the north or northeast. Its origin is ascribed to late tectonic, inhomogeneous, nonaffine shearing, and is believed to represent the final structural development in the schists of the corridor, attending late-stage doming of the Lexington batholith. The shear-dislocation of crests and troughs of minor folds may, but not necessarily, have taken place concurrently with the development of the lineation.

Large bulbous masses of quartz, and ptygmatically folded quartz veins are common in the southern part of the corridor. The axes of the ptygmatic structures generally plunge southwesterly. Where armored by quartz, pink, fresh andalusite and occasionally blue cordierite have been found. Swarms of chiastolite, preserved as white mica pseudomorphs, and abundant tourmaline commonly line the walls of the quartz bulbs and veins. This rather varicose geometry of the quartz-congested plumbing system may represent deformation of previously more planar structures, but more likely, simultaneous growth of the structures and sweating out of these constituents from the schists in a mileau of ductile deformation, which began in the first dynamothermal event and ceased during the second. There is no evidence that this hydrothermal system or the source of boron can be genetically traced to the crystallization of mafic or sialic magmas; rather, the decreasing concentration of boron (tourmaline: axinite (?)) into the mafic and granitic plutons suggests that it originally accumulated in the pelitic sediments at the time of deposition.

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2 A petrographic study of the pseudomorph-bearing schistose layers at stop 6, carried out by P.T. Lyttle, shows that the Al_2O_3- constant reaction:

$Biotite_a + Andalusite + H_2O \rightarrow Muscovite + Biotite_b + Chlorite + Quartz$

may require at least 0.1 mole of K^+ introduced per mole of andalusite altered to muscovite.

Microprobe analysis across a large chiastolite pseudomorph containing a core of fresh andalusite shows that a thin, discontinuous zone of pyrophyllite separates part of the fresh core from surrounding muscovite.

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Trip A-2

Road Log

Trip will start from Rangeley at 8:00 a.m. Assemble near Rangeley Inn. We will proceed directly to Kingfield; all localities for the trip are in the northwestern part of the Kingfield quadrangle and southwestern part of the adjoining Little Bigelow Mountain quadrangle. J. Raabe will lead the discussion on stops 1 - 2a; G.M. Boone will lead the remainder of the trip.

Mileage

0.0 Proceed E on Rt. 4 to Madrid and Phillips; at Phillips proceed NE on Rt. 142 to Kingfield.

38.0 Turn right, at termination of Rt. 142 in Kingfield, approximately 0.2 mile SE on Rt. 16 to bridge over the Carrabassett river. Park beyond E end of bridge.

38.2 STOP 1. Madrid formation. Medium- to thickly-bedded calc-silicate layers, the exposure here in the river being somewhat more calcic than is regionally typical of the Madrid. Direction in which the nearly vertically dipping beds face is largely indeterminate here. The assemblage plagioclase-actinolite-epidote±biotite±garnet is typical of the low to intermediate regional metamorphic grade of this part of the Kingfield quadrangle. Major aspects of relict parallel bedding are preserved, although most of the small-scale textures are metamorphic. Lineation plunges steeply.

38.4 Return across bridge and proceed north on Rt. 16-27. We cross the unexposed north contact of the Madrid formation approximately a mile north of the village limits.

39.7 Turn left onto Deer Farm road (sign at corner); proceed 1.0 mile from turn-off to road-side outcrops of andalusite-staurolite phyllite of presumed lower Devonian age.

40.7 STOP 2. Cleavage and bedding here dip essentially vertically. This locality is more than a mile E of the ductile shear zone, but its essential features and relations to the structures observed here will be discussed (see preceding text by Raabe).

The pelite here reflects an intermediate grade of metamorphism, with layers 3-4 mm thick containing the assemblages biotite-staurolite-andalusite, and biotite-staurolite-chloritoid (see discussion by Boone).

41.7 STOP 2a, tentative. Weather permitting, we will proceed to the top of the hill where we will briefly point out some of the larger-scale features of the southern part of the Sugarloaf gabbro and its roof-rocks, before retracing our route back to the Carrabassett valley and Rt. 16-27. Poorly exposed glacial pavement in the field immediately east of the road at the crest of the hill exposes lower Devonian (?) fine-grained muscovite-chlorite phyllite.

Return to Rt. 16-27 and proceed north approximately 2.15 miles.

45.9 STOP 3. We have crossed the quadrangle boundary 0.5 mile into the Little Bigelow Mountain quadrangle, and the outcrop location is roadside just north of the circled route numbers on the topographic map. The dominantly pelitic sequence extending northward through the valley has been divided into two formations (see text) which are collectively referred to as the Seboomook (?) formation along strike southwestward. We are, then, here in the lower member (approximately 3500 ft. thick) of the Carrabassett formation. The member is dominantly "massive" throughout most of its extent, but we see here one of several well-bedded parts, made so by locally abundant interbedded quartz wacke.

NO HAMMERING HERE.

These well-bedded portions superficially resemble the Perry Mountain formation of upper Silurian (?) age, seen on trip A-1. Comparison shows, however, that the Perry Mountain is consistently well-bedded, and is more potassic (muscovite is much more abundant) in its pelitic layers. Ratio of Fe/Mg seems generally higher, but total Fe, Mg, is lower in the Perry Mountain than in the pelites of the Carrabassett or Seboomook formations.

The structures displayed here have lured the attentions of many. Locally known by a legion of geologists as "the butterfly fold", it is the femme fatale of Carrabassett tectonics. Interpretations of its structural history have also been legion, but I offer the following provocation: In the later stages of vertical stretching that accompanied shearing and flattening of folds, we witness here a zone of greater-than-normal vertical elongation, with a local quasi-uniaxial stress field, the orientation of least principal compressive stress plunging steeply southwestward, parallel to the lineation. Secondary, steeply plunging folds were created by a puckering of the section inward, the secondary axial surfaces somewhat radially disposed toward the axial zone of maximum elongation. We see this local geometry planed off near a zone of necking or boudinage, in which the central quartz bulbs represent local pressure shadows.

Although quartz-filled tension-gashes abound in the quartz wacke beds, some may wish to argue for initial development of this structure in post-depositional slumping in the sedimentary environment. "Tectonic inclusions" of quartz wacke surrounded by pelite may represent semi-coherent sand lumps rafted into place during a period of redeposition in the sedimentary trough.

Retrograde recrystallization from andalusite-cordierite grade to form biotite-muscovite-chlorite, will be discussed. Note the abundant tourmaline associated with the quartz bulbs.

Proceed north 1.7 miles.

47.6 STOP 4. This laterally extensive, vertical rock face exposes a biotitic metaquartzite member, representing one of several thick, discontinuous clastic depositional wedges in the central part of the Carrabassett formation. It is preserved here in a recumbent, doubly-plunging syncline. Here the style of deformation in a much more resistant lithic type can be observed. Medium to thick, well-graded beds face normally and dip moderately westward at the south end of the exposure. The axial surface descends close to or beneath the road-level at the north end of the outcrop; here minor recumbent folds can be seen in the axial zone. Garnetiferous aplite dikes and quartz-pyrite veins cut the structure.

Proceed north approximately 0.2 mile.

47.8 STOP 5. Location is 0.5 mile N of Kingfield-Jerusalem township line. Outcrops here display the typically "massive" characteristics of relict bedding, (or total lack of bedding) in the lowest member of the lower Devonian (?) section. The andalusite schist has been sheared and retrograded. There are well-displayed examples here of ptygmatic quartz veins bordered by clusters of large chiastolite pseudomorphs.

Proceed north approximately 1.2 miles, to sharp bend in road paralleling the abrupt bend in the Carrabassett River.

49.0 STOP 6a. We have crossed over the uppermost (calc-silicate) member of the Carrabassett formation, which crops out only at higher elevations on each side of the river. Stops 6a and b are located in the lowermost part of the Seboomook (?) formation, here used in a more restrictive sense than in the region to the southwest. An additional estimated thickness of 1800 feet of the Seboomook (?) is preserved in this western half of the quadrangle.

This and other sections of the formation are consistently graded-bedded, with graded sets ranging from 2 inches to a foot thick. Basal graywacke parts of the sets show wavy bedding, cross-bedding, and rarely, foreset terminations at their bases, which produce a false-crossbedded appearance with respect to the top of the subjacent metapelite.

Most of the section here faces SE, but we are in the axial zone of a major syncline and "top" reversals across subsidiary folds throughout this zone are common, as can be seen here to advantage. Also well exposed here and at stop 6b is the style of widely spaced shearing and rotation between and within minor fold segments.

A "porphyroblast-drag" lineation, to be discussed, plunges steeply in the usual SW direction; its relation to fold axes is best observed and discussed here as well as at the next stop (see comments in text of accompanying article). Small scale, quartz-rich streaky segregations occur parallel to bedding in the metapelite in the northern part of the outcrop; its control, however, is cleavage and not bedding, as observed in many locations where bedding crosses cleavage at high angles.

Well preserved idiomorphs of largely altered staurolite and chiastolite represent the first recorded phase of metamorphism associated with emplacement of the Sugarloaf massif.

Proceed around bend in road, 0.3 mile.

49.3 STOP 6b. The exposure of folds in the three dimensions: cleavage, the near-horizontal, and the normal to fold-axis plunge, is best afforded here, even though structural setting and stratigraphic position are similar to 6a. The moderate preferred orientation of andalusite is also well displayed, and the fabric diagram is based on measurements from this locality.

The itinerary from stop 3 to the present location has been across a uniform zone of prograde metamorphism related to the gabbro, in which biotite-andalusite-staurolite (±garnet ±cordierite) characterized the assemblages. For reasons reviewed in the accompanying article, higher-grade assemblages are not evident between here and the gabbro contact crossed by the highway 0.8 mile northward.

The second phase of metamorphism, keyed to the emplacement of the Lexington batholith, is also uniformly represented over this same section of the itinerary by retrograde metamorphism yielding brown biotite, abundant chlorite, and muscovite. Varied degrees of shearing and phyllonitization are visible in outcrops, but particularly in thin sections of these rocks.

One may note here, as in previous stops, that muscovite and feldspar are notably absent from the interior parts of quartz veins. Although there is some suggestion, from modal analysis and calculations involving standard metamorphic biotite $K/Al^{VI} + Al^{IV}$ ratios, that potassium metasomatism is necessary in the metapelites at outcrop localities 6a and b to account for the muscovite replacement of andalusite and staurolite, the calculated amount is slight (see accompanying article) and cannot be established with certainty. All the K needed for muscovitization of andalusite and staurolite may have been supplied by chloritized biotite.

Proceed north 1.6 miles.

50.9 STOP 7. This is the last scheduled stop of Trip A-2, and the location on the topographic map is Spring Farm, B.M. 789. LUNCH. (Weather permitting, we can proceed ahead to the small field at the intersection of the old road on right, just north of the bridge.)

We see here the outer part of the Sugarloaf gabbroic massif. Characteristic of much of the massif, the gabbroic rocks here are altered and in places sheared. Massif-wide observations and study of exposed contacts suggest that the massif was emplaced and became largely solidified before regional folding and tectonic activity ceased.

Preserved here in part, nonetheless, are olivine-bearing, pyroxene-rich layers and plagioclase-rich layers in a rhythmically-layered sequence. (Not all of the massif is so layered.) The massif can be said to have tholeiitic affinity if the presence of both ortho- and clinopyroxenes is taken as a standard criterion. The igneous rocks of the massif have not been systematically mapped or studied.

Note that the strike of the layering is perpendicular to that of the contact, and the layering here characteristically dips gently northward.

Return 8.5 miles to Kingfield (Farmington is 22 miles due south on Rt. 27); return to Rangeley by turning right onto Rt. 142 to Phillips; Rt. 4 Phillips to Rangeley.