TRIP A-3

THE CARDIGAN PLUTON OF THE KINSMAN QUARTZ MONZONITE

John B. Lyons and Russell G. Clark
Dartmouth College
Hanover, N. H.

Introduction:

This trip traverses the Cardigan pluton of the Kinsman Quartz Monzonite (Billings, 1956, Plate 1), and examines outcrops of this formation, of its wallrocks, and of the younger intrusives cutting it. Billings (1956) has classified the Kinsman as a magmatic rock, and as a member of the Acadian-age New Hampshire Plutonic Series. Chapman (1952), however, has proposed that it is a granitized pelite. Thompson et al. (1968, p. 208) suggested an anatectic origin, the protolith possibly having been a volcanic unit within the Littleton Formation.

Petrology and Structure:

Megacrysts of potash feldspar up to 12 cm. in length and abundance of garnet characterize the Kinsman throughout most of the Cardigan pluton, but there are areas, chiefly those in which shearing has been important, where garnet is absent. Contrasting mineralogies in the Kinsman appear to be controlled by the reaction:

$$\text{musc.} + \text{bio.} + 3\text{ q.} \rightleftharpoons 2\text{ K. fs.} + \text{gar.} + 2\text{ }H_2O$$

Ingress of water along shear zones drives the reaction toward the left; over most of the pluton, P, T, and a_{H_2O} are such as to favor the potash feldspar-garnet pair. Crystallization of garnet is induced by extremely low oxygen fugacity conditions, (cf. Hsu, 1968) which are caused by the widespread distribution of graphite within the Kinsman formation.

A close network of gravity stations over the portion of the Cardigan pluton visited in this excursion indicates that it is nowhere thicker than 2.5 km. We interpret the pluton to be a flat synorogenic sheet of contaminated magmatic rock which, when it had reached a semi-solid condition, was injected, probably along shear zones, by flat-lying pegmatites and aplites. All of these early-formed rocks were involved in a cycle of westward-overturning and recumbent folding. Renewed (or continued) folding produced a set of N-NE trending folds and, locally, a vertical axial plane cleavage. Breakdown and replacement of garnet by biotite probably occurred at this time. Finally, the Kinsman was intruded by the Spaulding Quartz Diorite, the Concord Granite and late-stage pegmatities and aplites.

The spectacularly large potash feldspar megacrysts of the Kinsman Quartz Monzonite are considered to be phenocrysts on the following evidence: 1) early time of crystallization, as shown by extreme cataclasis, 2) inclusions of zoned plagioclase (An_{26-35}) and of biotite aligned parallel to the major crystallographic planes of the K-feldspar host, 3) clear x-ray evidence, despite their present predominantly triclinic symmetry, that the original K-feldspar symmetry was monoclinic, 4) K/Rb ratios in coexisting biotite and alkali feldspar from the Kinsman lower than those in the Littleton schist, and showing a progression toward the high Rb concentrations characteristic of differentiated magmatic series, and 5) appropriate bulk rock chemistry to account for the presence of potash feldspar phenocrysts.

Whether the Kinsman magma originated <u>in situ</u> or at deeper levels is uncertain. We favor the latter alternative because of 1) the pervasive graphitic contamination, 2) the evidence, from contact reaction zones and from Mg/Fe ratios in coexisting garnet and biotite, of a higher temperature of crystallization than that of the wallrocks (Lyons and Morse, 1969), and 3) local and areal cross-cutting relations of the Kinsman with respect to its wallrocks.

REFERENCES CITED

Billings, M. P., 1956, The geology of New Hampshire: Part II Bedrock Geology. New Hampshire State Planning and Development Commission, Concord, New Hampshire, 203 p.

Chapman, C. A., 1952, Structure and petrology of the Sunapee quadrangle, New Hampshire. Geol. Soc. Am. Bull., v. 63, p. 381-425.

Hsu, L. C., 1968, Selected phase relationships in the system Al-Mn-Fe-Si-O-OH; a model for garnet equilibria. J. Petrology, v. 9, p. 40-83.

Lyons, J. B., and Morse, S. A., 1969, Mg/Fe partitioning in garnet and biotite from some granitic, pelitic, and calcic rocks. Am. Mineralogist, v. 55, p. 231-245.

Schreyer, W., and Seifert, F., 1969, Compatibility relations of the aluminum silicates in the systems $MgO-Al_2O_3-SiO_2-H_2O$ and $K_2O-MgO-Al_2O_3-SiO_2-H_2O$ at high pressures. Amer. J. Sci., v. 267, p. 371-388.

Thompson, J. B., Peter Robinson, T. N. Clifford, and N. J. Trask, 1968, Nappes and gneiss domes in west-central New England in E-An Zen, W. S. White, J. B. Hadley, and J. B. Thompson (eds.) Studies of Appalachian Geology, Northern and Maritime. Interscience Publishers, New York, p. 203-218.

Zen, E-An, W. S. White, J. B. Hadley, and J. B. Thompson, eds., 1968, Studies of Appalachian Geology, Northern and Maritime. Interscience Publishers, New York, 475 p.

MAPS

1. U. S. Geological Survey 15' Topographic Map of Mt. Kearsage, New Hampshire, Quadrangle, 1956.

2. Geologic Map and Structure Sections of the Sunapee Quadrangle, New Hampshire, Plate 1 in Chapman, C. A., 1952, Structure and petrology of the Sunapee quadrangle, New Hampshire. Geol. Soc. Am. Bull., v. 65, p. 381-425.

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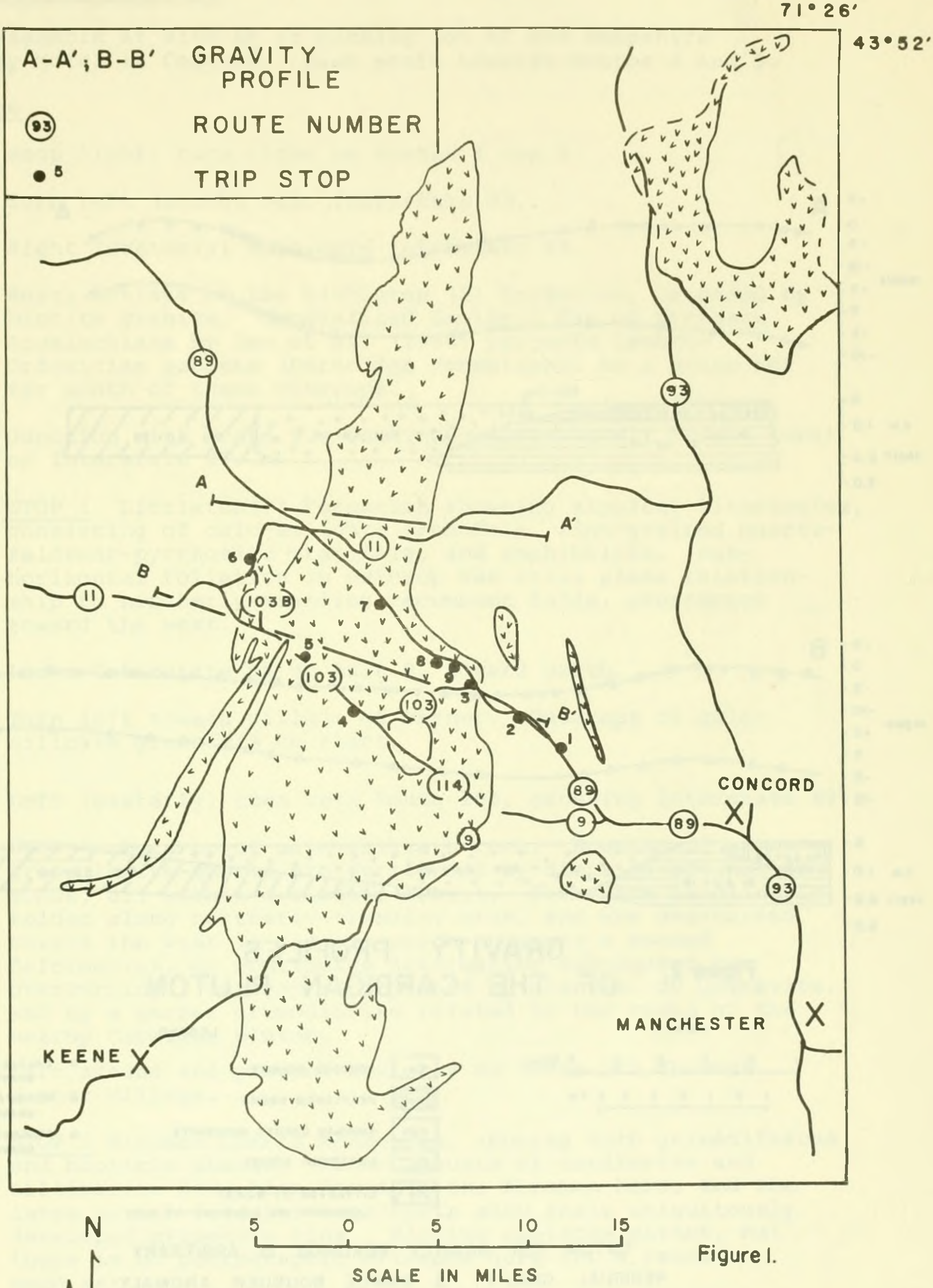


Figure I.

SKETCH MAP OF KINSMAN PLUTONS
WEST-CENTRAL NEW HAMPSHIRE
(after Billings, 1956)

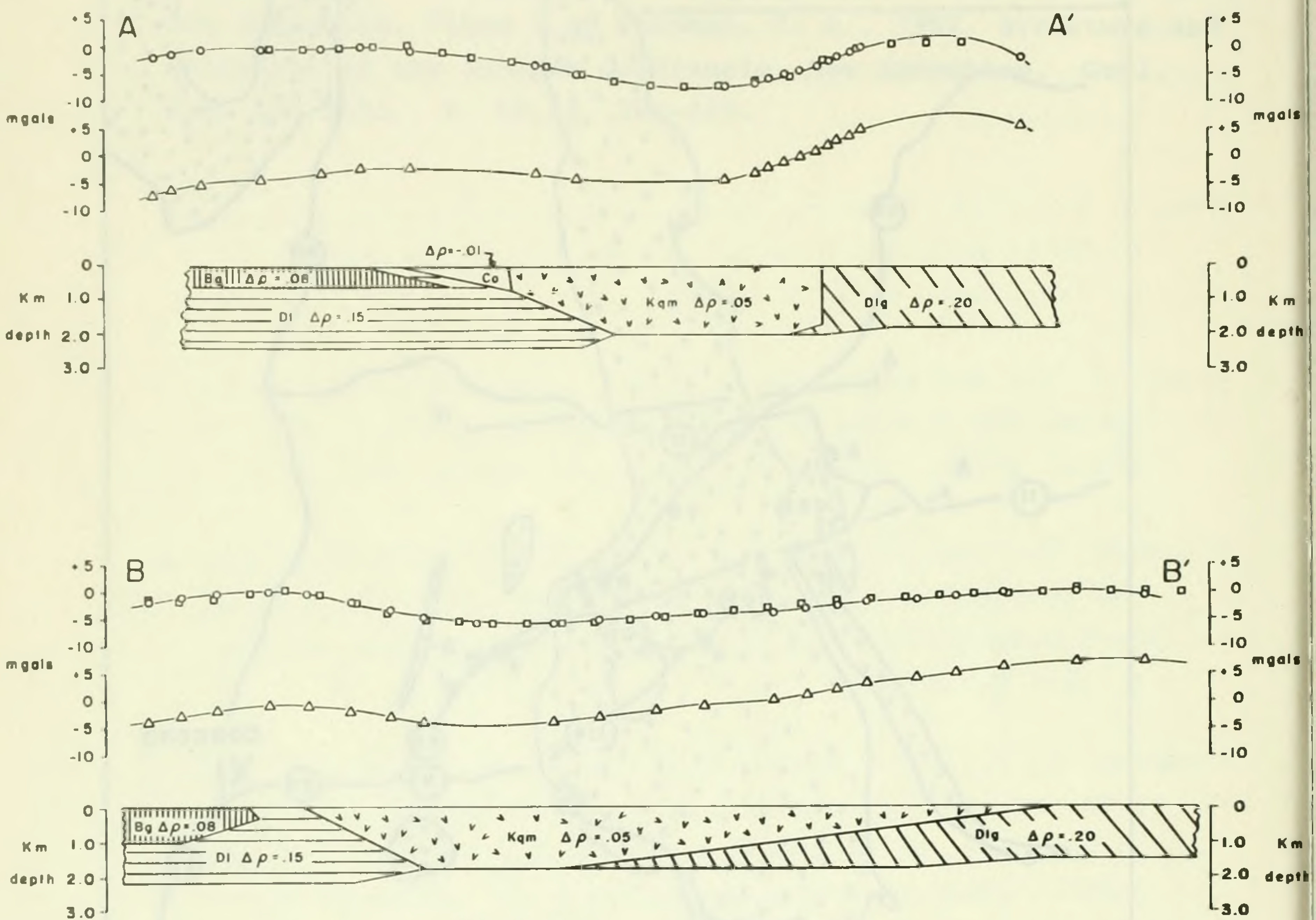
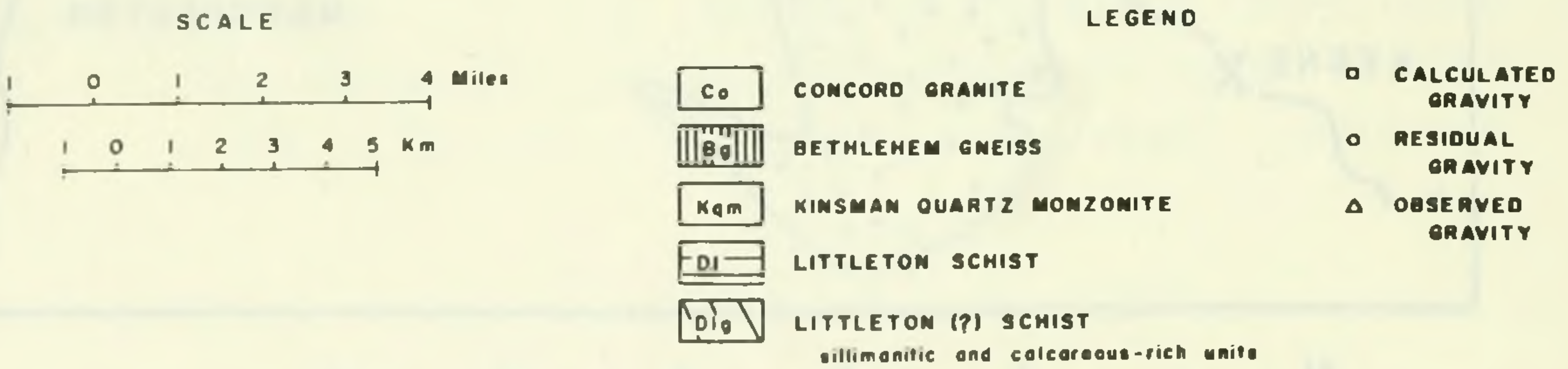


Figure 2. GRAVITY PROFILES OF THE CARDIGAN PLUTON



DATUM FOR GRAVITY READINGS IS ARBITRARY

RESIDUAL GRAVITY IS SIMPLE BOUGUER ANOMALY

ROAD LOG FOR TRIP A-3

Assemble at 8:00 AM at parking lot of New Hampshire Highway Motel in Concord. Heat south towards Routes 4 and 9.

Mileage

0.2 Stop light; turn right on Routes 4 and 9.

0.3 Turn left (south) onto Interstate 93.

3.1 Right (westerly) turn onto Interstate 89.

7.8 Rusty schists of the Littleton (?) Formation, intruded by biotite granite. Generalized Geologic Map of Northern Appalachians by Zen et al. (1968) projects Cambro-Ordovician schists (Partridge Formation?) to a point not far south of these outcrops.

11.7 Junction with Route 9. Continue northwesterly (right fork) on Interstate 89.

16.4 STOP 1 Littleton(?) Formation showning atypical lithologies, consisting of calc-silicate granofels, fine-grained quartz-feldspar-pyrrhotite granofels, and amphibolite. Sub-horizontal foliation in outcrop has axial plane relationship to northerly-trending recumbent folds, overturned toward the west.

20.7 Leave Interstate 89 on Exit 8, toward north.

21.0 Turn left toward village of Warner. Outcrops of calc-silicate granofels on right.

21.2 Left (easterly) turn onto Route 103, crossing Interstate 89.

21.7 STOP 2 Outcrop of calc-silicate rock. Boudins of grossularite-quartz are surrounded by diopside-actinolite zones, all within a biotite schist. Rocks are isoclinally folded along northerly-trending axes, and are overturned toward the west in a style which suggests a second deformation, or continuing deformation subsequent to overturning. Outcrop is injected by granite, by pegmatite, and by a garnet granodiorite related to the rocks of the nearby Cardigan pluton.

Turn around and proceed westerly on Route 103 through Warner Village.

24.9 STOP 3 Kinsman Quartz Monzonite, showing both garnetiferous and biotitic phases. Minor amounts of cordierite and sillimanite have been found in the Kinsman here, and the large potash feldspar megacrysts show their ubiquitously developed myrmekite rims. Biotite replaces garnet, but there is no petrographic evidence here for a reaction such as:

gar. + musc. $\rightleftharpoons$ bio. + sill. + q. Conversion of garnet to biotite may thus be a late-stage magmatic effect. Aplite intruding the Kinsman has been folded and faulted, and the potash feldspar megacrysts line up in the axial plane of one fold.

Gravity studies in the Cardigan pluton indicate that the maximum thickness of the Kinsman Quartz Monzonite is less than 2.5 km; at this outcrop it is less than 0.2 km. Although foliation dips steeply to the east, the wallrock envelope here slopes approximately 14° westward.

31.5 Intersection of Routes 114 and 103; continue west on 103. Outcrop on north side of road is Concord granite intruding Kinsman Quartz Monzonite.

32.6 STOP 4 Large road cut in the Kinsman, which here displays a sub-horizontal foliation, and is injected by pegmatite, aplite, and Concord granite. The notable feature here is the extensive development of 1 to 2 foot thick bands of garnet-plagioclase-quartz granofels. These bands, though on a smaller scale, are petrographically similar to the garnet ores mined in the past at various places in New Hampshire, but chiefly where there are large xenoliths of aluminous schist in the Kinsman.

35.8 Outcrops on both sides of road are similar to those at STOP 4, except that garnet ore occurs in an isolated pod, and the analyzed Kinsman here shows good evidence for the reaction:

$$\text{garnet} + \text{potash feldspar} + H_2O \rightleftharpoons \text{biotite} + \text{sillimanite} + 2\ \text{quartz}$$

37.2 Mountain Road goes off toward the left (south). A large fault zone on the southeast side of Mountain Road, 1/2 mile from Route 103 has yielded an illitic fault gouge (1Md muscovite) which is considered to be authignic. The K/Ar age on the illite is 157 ± 3 m.y. Two other similar fault zones in western N.H. have ages of 160±4 m.y.

37.4 STOP 5 Pre- and post-folding aplite, Concord granite, and pegmatite cutting the Kinsman. Garnetiferous and biotitic phases of the Kinsman are both extensively sericitized.

On the north side of the road, about midway along the outcrop, is a garnet granofels, separated from the rock to the west by a cordierite (65%)-plagioclase-phlogopite-sillimanite-garnet granofels.

40.4 Go left around traffic circle and enter road to Mt. Sunapee State Park.

41.4 Lunch stop.

42.2 Exit from Mt. Sunapee State Park, bearing left around traffic circle, and follow Route 103-B toward Sunapee village.

45.9 Turn right (northeasterly) at junction with Route 11.

46.2 STOP 6 Spaulding Quartz Diorite, intruded by pink pegmatite. Elsewhere (but not at this outcrop) it may be shown that the Spaulding intrudes the Kinsman.

The unusual feature of this outcrop is gneissic agmatite containing fragments of schist, vein quartz, pegmatite, aplite, and potash feldspars similar to those in the Kinsman. Pink potash feldspar xenocrysts in the agmatite create a special problem, because pink pegmatite dikes clearly cut the agmatitic rock. The outcrop is thought to represent a fluidized explosion vent which served as a channelway for the pegmatitic fluids. The xenoliths and xenocrysts presumably originate at deeper levels, but their precise site of origin is uncertain.

Continue on Route 11 through George's Mills toward New London.

51.2 Turn right (south) onto Interstate 89.

51.8 Large outcrop of Concord granite, intruded by a lamprophyre. Concentrations of autunite occur near the dike.

58.2 STOP 7 Kinsman, intruded by aplite and pegmatite, which have been folded along a N38E axial trend; some minor folds, however, are disharmonic, either owing to later folding, or to an inhomogeneous response of the rocks to deformation. A large xenolith (?) of schist (?) is of interest here. Note that it contains deformed K-feldspars similar to those in the Kinsman, and that myrmekitization post-dates cataclasis of the feldspars. Garnet in the Kinsman has been completely pseudomorphed by biotite.

63.9 STOP 8 Aplite dike, which becomes progressively boudined, and finally shredded as it passes into the nose of a tight recumbent fold. The schistose rocks here grade into the Kinsman, but the transition is thought to represent progressive cataclasis, rather than the transformation of Littleton schist into Kinsman-type rocks. Note the resemblance of the schistose rocks here to the xenolith (?) of Stop 7.

64.5 STOP 9 Spotted (fleckly) gneiss of the Littleton formation, showing garnet nuclei surrounded by microcline rims, the texture probably resulting from reaction and breakdown of biotite + muscovite.

The Kinsman enclosing the schists here is a granodiorite similar to that at Stop 2, containing the assemblage q-K.fs.-plag.-bio.-gar.-cord.-sill.-il.-ru.-sulfides. According to Schreyer and Seifert (1969) this assemblage suggests temperatures $\sim$695°C, and pressures $\sim$5 kb.

END OF TRIP. RETURN TO CONCORD (22 MILES) ON INTERSTATE 89.