METAGABBROS OF THE SOUTHEASTERN ADIRONDACKS: EVIDENCE FOR SEPARATE SYN-KINEMATIC, AND POST-KINEMATIC SUITES

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INTRODUCTION

This trip will explore some of the metagabbroic intrusions that dot geological maps of the eastern and central Adirondacks and are generally assumed to have been emplaced contemporaneously with the anorthosite massifs of the highlands (Fig.1). However, not only do most metagabbro intrusions in the southeastern Adirondack region lack the penetrative deformation fabric seen in the anorthosites and the host rocks, but many display chilled margins with sharp contacts that cut the foliation of the host gneisses.

Granoblastic texture and the presence of garnet coronas confirm that these rocks experienced granulite facies metamorphism, but without the strong deformation seen in most other rocks of the Adirondacks. Evidence of strain accommodation is limited to small, localized ductile shear zones well within the intrusive bodies. Could these rocks have been emplaced at shallow crustal levels, as is thought for the anorthosites, then buried to the 20-25 km depth necessary for granulite facies metamorphism, and yet somehow have escaped significant deformation? Stops will include several outcrops of undeformed metagabbros with clearly visible host rock contacts and chilled margins, as well as an example of deformed metagabbro with large, stretched garnet porphyroblasts.

GEOLOGIC SETTING

The Adirondack Mountains expose Proterozoic gneisses and calc-silicate rocks that host massif anorthosite, as well as smaller bodies of mangerite, charnockite and granite (known as the AMCG suite) emplaced during the Grenville Orogeny (1-1.3 Ga). Subsequent burial to mid-crustal depths of 20-25 km has been determined on the basis of geo-thermometry and -barometry of minerals in the granulite facies rock. By the Cambrian, the rocks had been exhumed and lay beneath the sea, evidenced by outcrops of Cambrian sandstones overlying Proterozoic gneisses, some of which can be seen in down-dropped blocks in the Lake George graben.

As a result of the convergence tectonics of the Grenville Orogeny, the rocks comprising the Adirondacks were strongly deformed, obliterating almost all original relationships among rock types, sometimes making the determination of even the original rock type difficult. While the pervasive deformation produced some spectacular large-scale fabrics (such as will be seen at Stops 5 and 6 on this trip), field interpretation of these rocks is often quite difficult.

ADIRONDACK METAGABBROS

Because metagabbros are distinctly different in color and texture from the ubiquitous gneisses of the Adirondacks, and because if they are intrusive igneous bodies we can make some assumptions about their pre-deformational structure, they could prove useful as benchmarks. Their identity is usually easily made in the field. They have a mineral assemblage of plagioclase + hornblende + garnet ± pyroxene ± olivine. Garnet coronas are present. And as will be seen from this trip, they fall into two rather clear categories: those that have been severely deformed, and those that have not and retain many relict igneous features. The purpose of this trip is to acquaint participants with the field markers of each category and to present a sampling of the locales at which they can be observed.

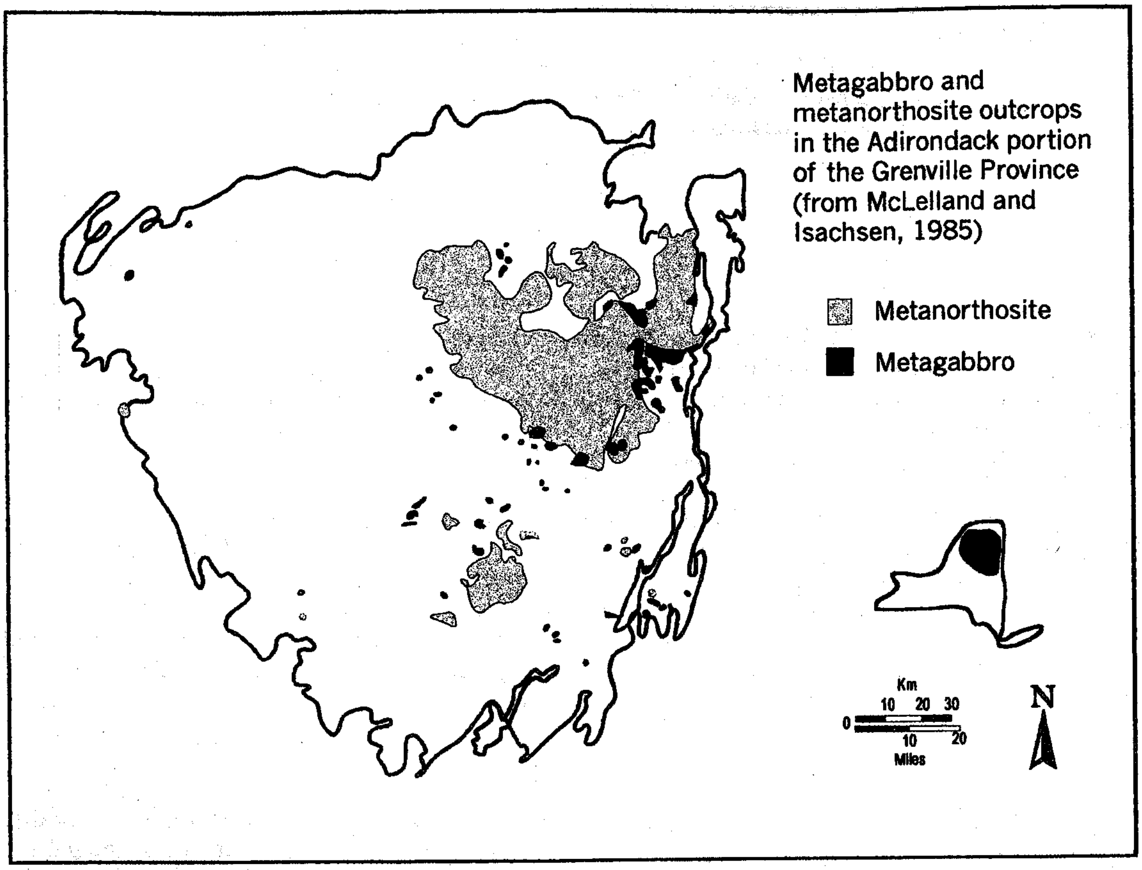

Figure 1. The distribution of metagabbro bodies in the Adirondacks. It should be noted that this map shows only those outcrops large enough to be mappable at this scale.

REFERENCES

Alcock, J. and Muller, P., 1999, The ca. 1144 Ma Dresden Station metagabbro: a re-evaluation: Northeastern Geology and Environmental Sciences, v.21, no. 4, p.275-281.

Fisher, D. W., 1984, Bedrock Geology of the Glens Falls-Whitehall Region, New York, New York State Museum, Map and Chart Series Number 35, 58 pp., map.

McLelland, J., and Isachsen, Y., 1985, Geological evolution of the Adirondack Mountains: a review, *in* Tobi, A., and Touret, J., eds., The Deep Proterozoic Crust of the North Atlantic Provinces: NATO Advanced Studies Inst., v. 158, p.175-217.

McLelland, J., Lochhead, A., and Vyhnal, C., 1988, Evidence for multiple metamorphic events in the Adirondack Mountains, New York: Journal of Geology, v.96, p.279-298.

Valley, J.W. and O'Neil, J.R., 1982, Oxygen isotope evidence for shallow emplacement of Adirondack anorthosite: Nature, v. 300, p.497-500.

ROAD LOG

Most of the outcrops on this trip are roadcuts, but require short walks from where vehicles are parked. PLEASE use utmost CAUTION at roadcuts. Always stay inside guardrails, or well onto shoulders, if there is no guardrail.

One stop requires a short hike (~2 miles round trip) on easy to moderate terrain. Bring a lunch to eat at a pond on the hike. Hiking boots are not a must, but won't hurt either. A hand lens will be useful. No need for hammers.

Prospect Mt. is best accessed by the toll road. The fee is $5.00 per car.

Mile

0.0 Start at parking lot of Fort William Henry Inn, 48 Canada Street, Lake George, NY.

0.1 Turn left onto Canada St.

1.0 At 2nd traffic light, turn right onto Rt. 9N.

1.1 Turn right into Ramada Inn and park behind motel. Walk south, cross Rt. 9N and proceed south on I-87 exit ramp to outcrop on E side of the ramp. STAY OUTSIDE GUARDRAIL AND WATCH FOR TRAFFIC!

STOP 1. INTERCHANGE 21 ROADCUT. Lat 43° 24.125′ N Lon 73° 42.599′ W (30 MINUTES)

At the N end of the outcrop E of the exit ramp,is gray granitoid gneiss with small migmatitic veins and pods, some of which contain 0.5 cm hornblende crystals. ^{40}Ar-^{39}Ar dating of biotite from this outcrop yielded a cooling age in the range of 750-850 Ma (Heizler and Harrison, 1998). Note that the gneissic foliation dips E (280°/40°E), as does most of the regional fabric. Close examination shows small areas of low-grade alteration, a result of contact with fluids during exhumation.

Carefully, climb to the top of the outcrop and proceed S, watching for the contact between gneiss and metagabbro. Partially buried in sand, it is best exposed at the edge of the outcrop where very fine-grained metagabbro sharply truncates the foliation in the gneiss. Just to the left (S) of the contact, a xenolith of gneiss is enclosed in metagabbro. Another gneiss xenolith is seen on the face of the outcrop (Fig. 2).

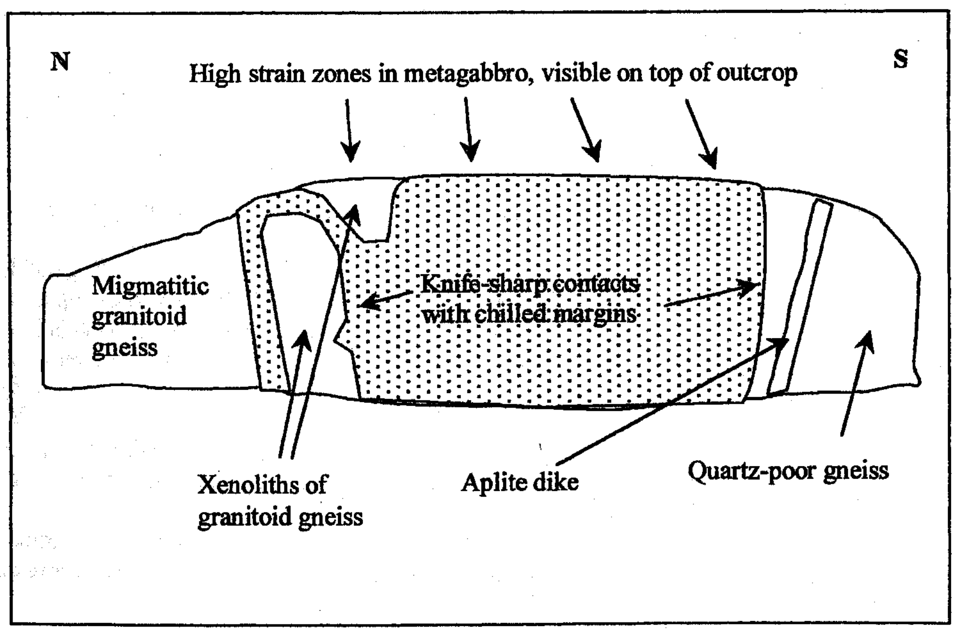

Fig.2 Stop 1. Interchange 21 Roadcut. Diagram of outcrop lithologies and structural features. (not to scale)

Continue to walk S along the top of the outcrop observing the coarsening of grain size in the metagabbro. Over ~2-3 m the grains become large enough to show clearly the relict igneous texture, i.e., ophitic or subophitic, in which the spaces between the more numerous plagioclase grains are filled by mafic mineral grains. With a hand lens, tiny pale, pink garnets can be seen to "decorate" the plagioclase, evidence that the gabbro was metamorphosed at granulite facies conditions.

Within the coarse-grained metagabbro are several areas that can be seen to have reacted ductilely to localized, intense strain. Determine the sense of shear for each. Are they consistent? Why are they located well within the metagabbro body, rather than nearer the contacts?

Walking S, metagabbro grain size decreases as the contact with a quartz-poor gneiss is approached. Again, the contact is sharp, truncates foliation in the gneiss (although this gneiss is less strained than that at the N end) and the margin was very obviously chilled against the cooler host rock. A meter or so into the gneiss, an aplite dike can be seen. Look carefully at the gneiss for feldspar porphyroclasts.

Returning N, stop in the middle of the metagabbro and look W at the outcrop across the exit ramp. One of the trip leaders always *assumed* that the outcrop was a continuation of the metagabbro, until the other checked it out and found that it is is the same gneiss as that at the N end of the E-side outcrop. When the orientation of the contacts are mapped and projected, it is seen that the contacts are not parallel and their projections intersect in the middle of the ramp. In other words, this intrusion is not a planar structure.

The field evidence from this outcrop can be used to set up a geological scenario for the intrusion of the host rocks by the gabbro. The truncated foliation shows that the host rocks were already deformed when the gabbro intruded. The sharp contacts indicate that the host rocks were cool enough to behave brittlely. The chilled margins in the metagabbro indicate that a temperature difference existed, which is not surprising given that the host rocks were brittle and the gabbro was a melt. So far, this is a typical scenario for magmatic intrusion. The puzzle arises when we attempt to account for the facts that the metagabbro shows granulite facies mineral assemblages, as do the gneisses, but unlike the gneisses, the metagabbro is not pervasively deformed.

1.1 Return to car. Leaving motel parking lot, turn left on Rt. 9N.
1.3 Turn left at light and proceed north on Rt. 9. Stay in left lane.
1.7 At 2nd light, turn left onto Prospect Mt. Highway.
2.5 Toll Booth ($5.00/car).
4.1 Overlook 1.
4.7 Overlook 2.
5.0 Park at Overlook 3 and take a moment to enjoy the view of Lake George, which lies in an Ordovician-aged graben.

STOP 2. METAGABBRO "FINGERS". Lat 43° 25.995′ N Lon 73° 43.869′ W (20 MINUTES)

Carefully cross the road to the outcrop which places you in the vicinity of the two "fingers" labeled **1** and **2** in Fig. 2. You will be able to trace out several faces and contacts of these intrusions, showing that these are more planar in shape than the intrusion at the Stop 1. Notice that they are very fine-grained. This is likely because they chilled uniformly due to their thinness. But like the Stop 1 intrusion, the contacts here are very sharp. Close inspection shows truncated foliation.

Two more fingers occur to the left (SE). The second of these, **4** on Fig. 2, is indicated by a rounded shape with dashed lines because its contacts are vague. Take a look at this one and see what you make of its contacts.

Why do we call these intrusions "fingers"? Because they occur in proximity, the assumption is that they are finger-like protrusions of a larger (hand-like) intrusive body, that worked their way into an array of fractures in brittle-regime host rock.

Contacts and faces of the fingers can be seen on top of the outcrop as well.

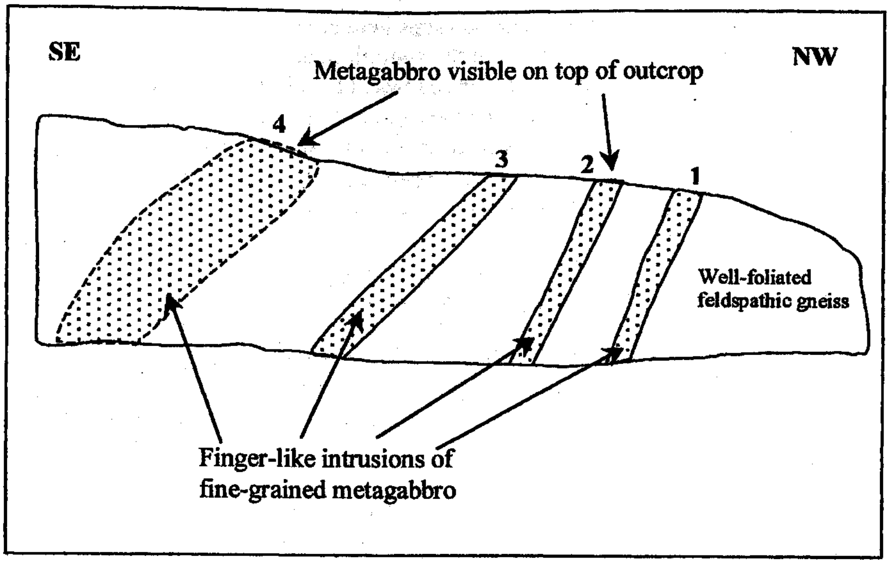

Fig.3. Stop 2. Metagabbro "Fingers" on Prospect Mt. Diagram of location and orientation of metagabbro "fingers" in gneiss host rock (not to scale).

5.0 Leave parking area and bear right, continuing up Prospect Mt. Highway.
7.2 Highway ends in large parking area just below the summit.

STOP 3. SUMMIT OF PROSPECT MT. Lat 43° 25.487′ N Lon 73° 44.789′ W (40 MINUTES)

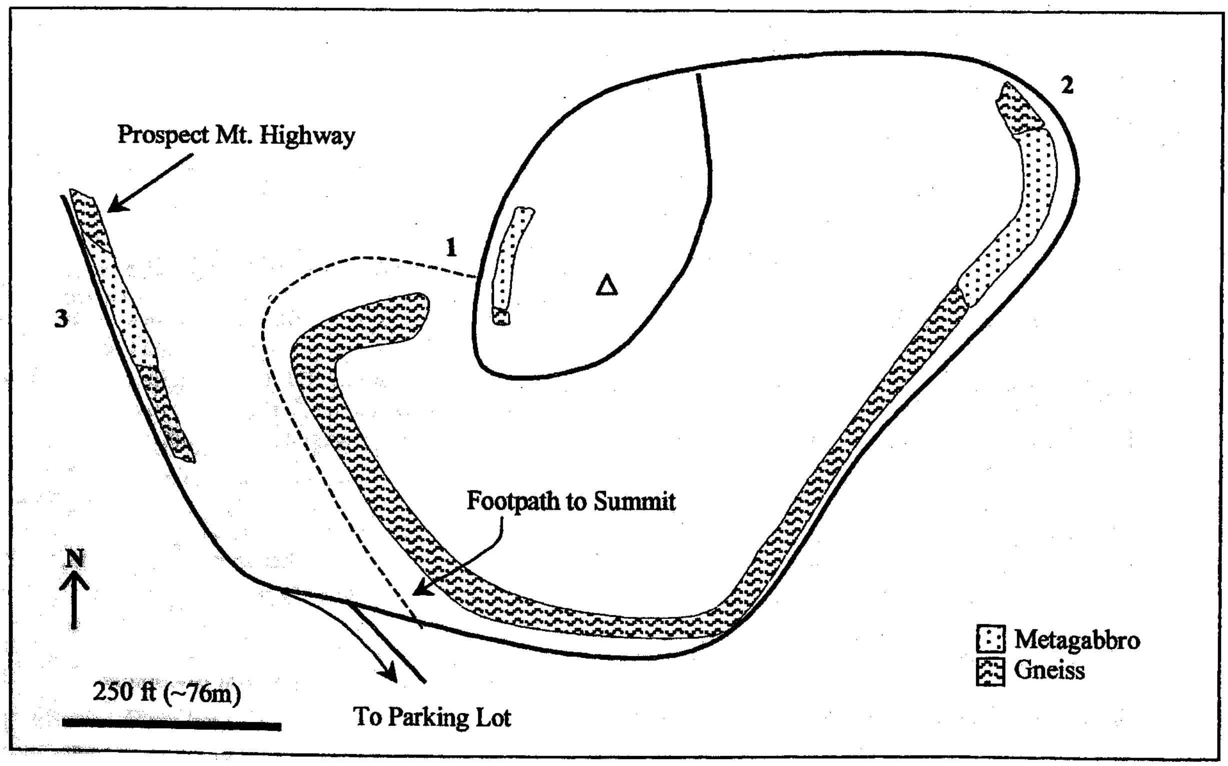

Fig.4. Stop 3. Sketch map of outcrops on top of Prospect Mt.

Walk north and find footpath to summit. The outcrops here are gneiss, largely lichen-covered. A flight of steps near the summit brings the footpath to an end at the summit roadway. (Fig. 4). Cross the road and head for the top. Then backtrack NW to the outcrop next to the roadway (1 on Fig.4). At the S end of the outcrop, reddish-weathered metagabbro is cut by a pegmatite dike. To the right of this, there is a block of metagabbro that looks at first to be detached. A closer look shows that this block is still in place and is underlain by gneiss. The contact strikes 350° and dips 40° N. Like the fingers seen at the previous stop, this exposure of metagabbro appears to be mostly fine-grained. There is no contact visible at the N end of the outcrop.

Continue around the roadway to the NE. Where it begins to loop back toward the SE, there is a large roadcut on the right (W) side of the roadway (2 on sketch map). About 150 ft. (~50 m) into a mass of quartzo-feldspathic gneiss, a contact zone with fine-grained metagabbro is seen. Here there is no sharp contact, but rather a zone in which small blocks of gneiss appear as inclusions in the metagabbro, and vice versa. This intrusion shows coarsening away from the contact. Pegmatite intrusions can be seen with retrograde biotite in the adjacent metagabbro. The S contact of metagabbro and gneiss is a rounded, "bullnose" structure striking 352° with a 50°E dip.

Outcrop 3, on the sketch map (Fig.4), will not be visited on this trip. It consists of a metagabbro intrusion into gneiss with sharp contacts, chilled margins, and localized shear zones within the metagabbro. Although it has not been established in the field, the three outcrops of metagabbro could be connected in the subsurface. Referring to Fig. 4, it can be seen that the intrusions share a similar orientation within the host rock.

Follow the roadway past monotonous walls of gneiss to the parking lot.

7.2	Leave parking area and proceed down Prospect Mt. Highway.
9.9	Overlook 1.
12.5	Jct. Prospect Mt. Highway and Rt.9. Turn right on Rt. 9.
13.0	Turn right at light.
13.1	Turn right onto northbound ramp of I-87.
15.0	Pass Exit 22.
17.5	Pass large pegmatite that intrudes metadiabase. DO NOT STOP.
17.6	Contact of metadiabase and gneiss (covered).
19.2	Bear right for Exit 23.
19.3-19.4	Just past the end of the guardrails on the exit ramp, pull over and park WELL OFF THE SHOULDER. Using EXTREME CAUTION, walk back to the roadcut, walking on the OUTSIDE of the guardrail.

STOP 4. I-87N EXIT 23 ROADCUT. Lat 43° 28.965′ N Lon 73° 45.280′ W (20 MINUTES)

Begin at the N end of this large (~250 m) body of metagabbro. The N contact with the host rock is not exposed. The first 100 ft. (~30 m) shows fine-grained metagabbros enclosed in more coarse-grained rock, suggesting the coarser rock was back-intruded by the finer-grained rock. At about 100 ft. (30 m), the metagabbro is well-foliated for about 30 ft. (10 m). Then a complex zone is seen, in which a 1.5 ft. (0.5 m) -wide pegmatite intruded a 10-ft. (3-m) shear zone in the metagabbro. The zone has also been disrupted by a fault. The shear zone strikes 66°and dips 70° W and has a left lateral shear sense.

Continuing along the outcrop, many pegmatite intrusions of varying sizes are seen. The metagabbro displays subophitic texture and is quite coarse grained. At about 350 ft. (105 m), another shear zone occurs, about 3 ft. (1 m) wide, showing left lateral shear sense. Several more smaller shear zones are seen.

The metagabbro begins fining as the contact with Grenville metasedimentary rocks is approached. The contact is sharp. Look closely at the metasediments. They are strongly foliated, having been isoclinally folded. Metamorphic minerals in these rocks include phlogopite, diopside and garnet.

Return to vehicles, being careful to remain outside of the guardrail.

19.4 Proceed to end of ramp and turn left.

19.7 Turn left (S) onto ramp to I-87 southbound.
25.8 At Exit 21 leave I-87.
26.1 Turn left at end of ramp.
26.5 Turn right at light, proceeding south on Rt 9.
29.0 Turn left (E) at light onto Rt. 149.
32.1 Jct. with Bay Rd. Continue east on Rt. 149.
33.5 Jct. with Rt. 9L. Continue east on Rt. 149.
35.0 Turn right (N) onto Buttermilk Falls Rd.
38.1 Buttermilk Falls Rd. ends; continue north on Sly Pond Rd.
41.4 Parking area on left (guidebooks refer to this as the Lower Hogtown Parking Lot, but there is no sign).

STOP 5. TRAIL TO INMAN POND. Lat 43° 29.339′ N Lon 73° 34.237′ W (60 MINUTES)
Bring your lunch along.

The trail enters the woods from the parking lot and follows a stream on the right (N). Bedrock in the trail is quartzo-feldspathic gneiss, with occasional float (loose) blocks of metagabbro and marble/calc-silicate rock. At a little over a half mile (0.8 km) there is a faint trail on the right (N) that leads to the outcrops. For now, pass that by and continue W toward the pond. At 0.7 mile (1.2 km) a clear trail to the right leads to the north shore of Inman Pond. At 1 mile (1.6 km), there is a stone fire ring in a grove near the water. Lunch!

Return to the first side trail, now on the left (N) and turn onto it. Proceed at a slight angle to the left of the trail and continue right up to the outcrops (1 on Fig.6). The metagabbro here is quite different than what was seen at the previous stops. It has a coarser texture, and is studded with garnet porphyroblasts in the 3-cm range, that have amphibole rims. Look for a block that displays perpendicular faces. The garnet porphyroblasts appear fairly equant on one face of outcrop, but on the perpendicular face they are strongly elongated, with felsic pressure shadows.

A half foot (15 cm) -wide felsic layer is seen within the garnet-bearing metagabbro. It is presumed to have come from the nearby gneiss, perhaps by partial melting of the gneiss during metamorphism. Proceed to the E, noting the change in outcrop to gneiss, and continuing until the faint side trail is encountered. Turn left (N) on the trail. Outcrop 2 (Fig.6) is on the right side of the trail about 100 feet (30 m) ahead, depending on where the trail is picked up.

This outcrop displays a contact zone between metagabbro and gneiss. While there are remnants of the sharp contacts formed when the metagabbro intruded, they are severely disrupted and in some places foliation is continuous across both lithologies. A lens-shaped body of metagabbro is seen, as well as small areas of interfingering between the two rock types. There can be no doubt that this metagabbro was deformed along with the gneiss, and must have been emplaced prior to the peak of dynamic metamorphism.

From Outcrop 2, proceed southeast to outcrop 3, crossing a small ravine and scrambling up a small hill. Continue to the SE edge of the hill, where outcrops will be more numerous. Climb down a bit to find a 10 ft (3 m) -high ledge of interlayered marble, gneiss and strongly foliated metagabbro. The bottom layer is marble with small pods of coarse-grained metagabbro. Above that is a layer of gneiss, with an area of mylonitic fabric near the face of the outcrop. Another layer of gneiss is above that, but this layer has a pronounced oblique fabric that is truncated by yet another layer of horizontally layerd gneiss. This is capped by marble that contains inclusions of folded gneiss.

While a fascinating outcrop in its own right, the relevance to the metagabbro question is that here the metagabbro has been severely dismembered, included in marble and incorporated into a mylonite. Very different from what was seen at the first 4 Stops of this trip.

From here, proceed down the slope to the S and the trail will be encountered in about 300 ft (100 m). Turn left (E) onto the trail and return to the parking lot.

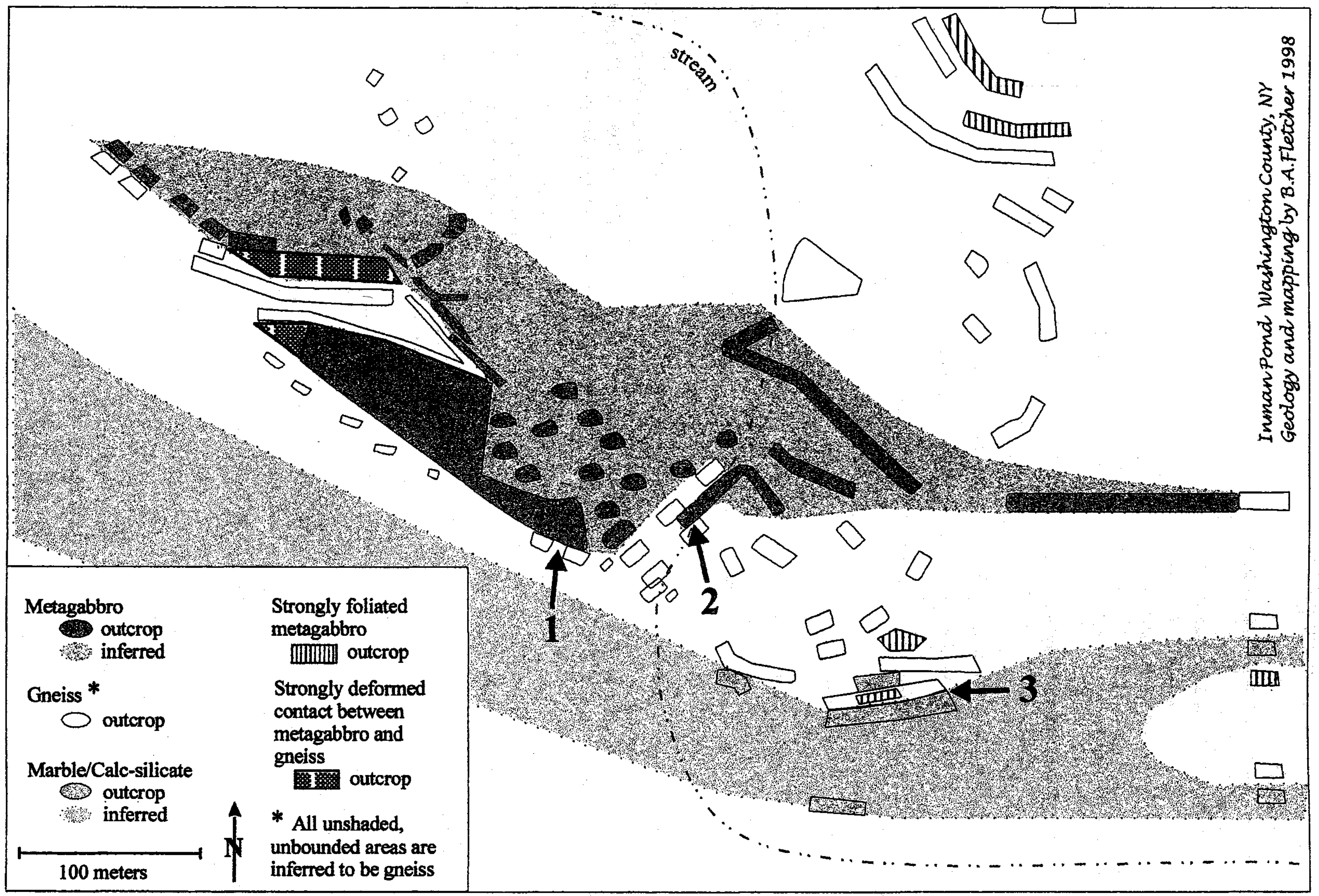

Fig. 6 Stop 5. Outcrops east of Inman Pond. Simplified geologic map showing syn-kinematic intrusion of metagabbro that was strongly deformed along with the host rocks. Numbered arrows refer to outcrops in the text.

41.4 Leaving parking area, turn right (south) on Sly Pond Rd.
44.6 Bear right onto Buttermilk Falls Rd.
47.7 Turn left (east) onto Rt. 149.
53.4 Turn left (north) at light onto Rt. 4 in village of Fort Ann.
57.2 Jct. Rt. 22
57.6-57.7 Roadcut on right. Carefully pull onto shoulder.

STOP 6. METAGABBRO BOUDINS. Lat 43° 27.544′ N Lon 73° 26.670′ W (10 MINUTES)

This spectacular roadcut provides another example of gabbros that were fully involved in the deformation event that produced the Adirondack gneisses, i.e., that were intruded syn-kinematically. On the east side of the road, two large pods of metagabbro are seen. They are continuous with those seen on the left (W) side of the highway. The formation of boudins is the result of competency contrast during deformation, usually folding of a more competent layer surrounded by a less competent layer. The competent layer deforms more brittlely than the less competent layer. However the stretched out tails of the metagabbro layers show that they deformed ductilely as strain continued after boudinage.

57.6-57.7 Return to car. Continue north on Rt. 4.
63.3 Sign for village of Whitehall.
63.9 Jct. Rts. 4 and 22. Proceed north on Rt.22.
66.4 Cross bridge over Lake Champlain.
74.3 Pass road to Dresden Station on right.
74.8 Pass road from Dresden Sta. on right.
75.0 Turn right onto Belden Rd.
75.1 Park on Belden Rd. immediately behind outcrop.

STOP 7. DRESDEN STATION METAGABBRO Lat 43° 40.734′ N Lon 73° 24.655′ W (30 MINUTES)

Walk S on Belden Rd. and turn left (E) onto Rt. 22. BE VERY CAUTIOUS. Traffic moves swiftly and the curves in both directions limit the sight distance. Proceed about 300 ft (100 m) and find a sharp contact between metagabbro and gneiss. Here the gneiss is a khondalite, a name given to aluminous gneisses of sedimentary origin. This one contains purplish garnets, some of which are truncated by the metagabbro. Once again, there are small areas of ductile shear in the metagabbro.

The metagabbro continues across the road, but is harder to trace because the contact between gneiss and metagabbro is subparallel to the face of the roadcut, and the metagabbro is thin or absent in some places. However, on top of the W end of the outcrop the intrusion and its contact are clearly seen.

75.1 Return to car. Turn around and drive back to intersection of Belden Rd. and Rt. 22.
75.2 Turn left (south) on Rt. 22.
83.8 Cross Champlain Bridge.
86.3 Jct. Rts 4 and 22 in Whitehall. Proceed south on Rt. 4.
96.8 Turn right (west) on Rt. 149 in Fort Ann.
111 Jct. of Rts. 149 and 9 in Lake George.

To I-87 North:
Turn right (N) on Rt. 9
Turn left at first light onto Rt. 9L.
Turn right onto ramp for I-87N.

To I-87 South:
Turn left (S) on Rt. 9
After passing through shopping district, turn right at light (Montcalm Restaurant is on corner).
Turn left onto ramp for I-87S.

New England Intercollegiate Geological Conference

94th annual meeting

New York State Geological Association

74th annual meeting

Guidebook for Fieldtrips in New York and Vermont

Lake George, New York
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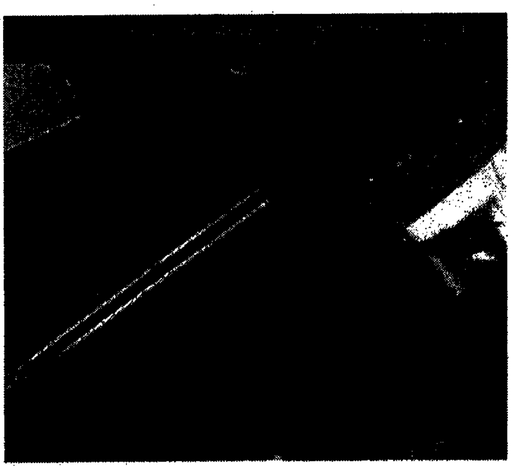

CL image of ca. 1155 Ma igneous zircons from the Marcy Anorthosite

Ca X-ray map of spiral garnet from the Gassetts Schist

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