Geology of the Adirondack-Champlain Valley boundary at the Craig Harbor faultline scarp, Port Henry, New York

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LOCATION

Port Henry is a small incorporated village on Lake Champlain, within the Town of Moriah in Essex County of northeastern New York. The Craig Harbor site is at approximately 44°03′30″N and 73°27′08″W, within the Port Henry 15-minute Quadrangle (Fig. 1). The major state highway through Port Henry is New York 9N/22, but the village can also be reached from I-87 (the Northway) off Exit 31 onto 9N south from Westport, or from Exit 30 east on County Road 6 to Mineville, south on County Road 7 to Moriah Center, and southeast on County Road 4 to Port Henry.

The Beach Road turns eastward off Main Street at the base of the fault-line bluff on which the village is situated, and parking is available at a public boat launch and picnic area to the north of the road (Fig. 1). Walk north through the Villez Marina (a local landmark facility!) and up onto the adjacent Delaware and Hudson railway. Exposures of the site extend north about 1,650 ft (500 m) to Craig Harbor, but excellent exposures also continue for many kilometers along the railway and lakeshore. Stay off the tracks themselves, as approaching trains are difficult to hear around bends in the railroad cuts and may appear suddenly.

SIGNIFICANCE

Deep railroad cuts, fault-line bluffs, and wave-cut exposures combine to illustrate the structures, Proterozoic basement rocks, and Lower Paleozoic stratigraphy that characterize the abrupt boundary between the eastern Adirondack Mountains and the western Lake Champlain Valley (e.g., Walton and deWaard, 1963; Isachsen and Fisher, 1971). This outstanding section along the Delaware and Hudson Railroad near Craig Harbor has stimulated interest in Adirondack geology for more than 150 years. The site shows field relations of Proterozoic "Grenville" marbles and calc-silicate rocks, older (?) basement granitic gneisses, lenses of metagabbro, a magnetite ore body, part of the shelf sequence of Paleozoic carbonate rocks, faults that juxtapose the rock units, and resultant structurally controlled landforms.

SITE INFORMATION

Partly because of important magnetite ores mined since the 1780s, the Delaware and Hudson Railroad was pushed through Port Henry with great effort in the mid-19th century. Many deep cuts and several tunnels were necessary to provide room for the railbed along the precipitous cliffs that border the Adirondack dome to the west and the Lake Champlain Valley to the east. This site provides a traverse across the northern edge of the Port Henry fault block on which the village is constructed (Fig. 1), and illustrates some of the Lower Paleozoic sedimentary units that overlie Proterozoic basement rocks along much of the eastern border of the Adirondacks.

Paleozoic Rocks. Although basal conglomerates of the Cambrian Potsdam Sandstone are well exposed in southern areas of Port Henry (Kemp and Ruedemann, 1910), rotation of the fault block down to the northeast has preserved the Cambrian Ticonderoga and Ordovician Whitehall carbonate units that overlie the Potsdam in this area (Fig. 1). The Paleozoic section is thickest (an estimated 800 ft; 250 m) and best exposed immediately south of Craig Harbor. Good summaries of the Paleozoic stratigraphy of the western Lake Champlain Valley are provided by Welby (1961) and Fisher (1968).

Along the railway above Villez Marina, dark sandy dolostone of the Cambrian Ticonderoga Formation is characterized by crossbedding, channel depressions, and blue-black chert layers and nodules. Some of the contortions and broken appearance of the dolostone mask the generally low, easterly dip angles of the layers. High-angle faults and attendant breccias are visible at several places in the cliff walls, with offsets of a few cm to a meter or more (Fig. 2A). The Ticonderoga Dolostone is measured by Welby (1961, p. 99) as 300 ft (90 m) thick in the Port Henry area.

Within a few hundred meters north of the marina, the cliff walls angle westward to open a swale that once contained a crushing mill. Although hidden behind woods now, a quarry near to the west once produced carbonate flux material for local iron furnaces and for road building. North of the swale there appears a lighter, more uniform "dove-colored" carbonate unit mapped as Ordovician Whitewall Dolostone, a lower unit of the Beekmantown Group that is also 300 ft (90 m) thick, according to Welby (1961). Beds of this dolostone unit dip to the northeast more steeply than do the Ticonderoga layers, and Kemp and Ruedemann (1910) inferred the presence of a fault through the swale that separates what was then known as Beekmantown divisions A and B (Fig. 2). Another possibility is that the northern outcrop of dolostone is part of the overlying Ordovician Cutting Formation, and the Whitewall Dolostone is not exposed because of downfaulting.

Proterozoic Rocks. The railroad bed crosses the mouth of Craig Harbor (known as Crag Harbor before being misnamed on the USGS maps of the 1890s) and should be traveled quickly so as to avoid conflict with trains. The northern wall of the embayment is a 165-ft-high (50-m)-high fault scarp representing the northernmost end of the Port Henry fault block where it bounds the Proterozoic with the Paleozoic sections.

In the upper west cliff face, a white "Grenville" marble

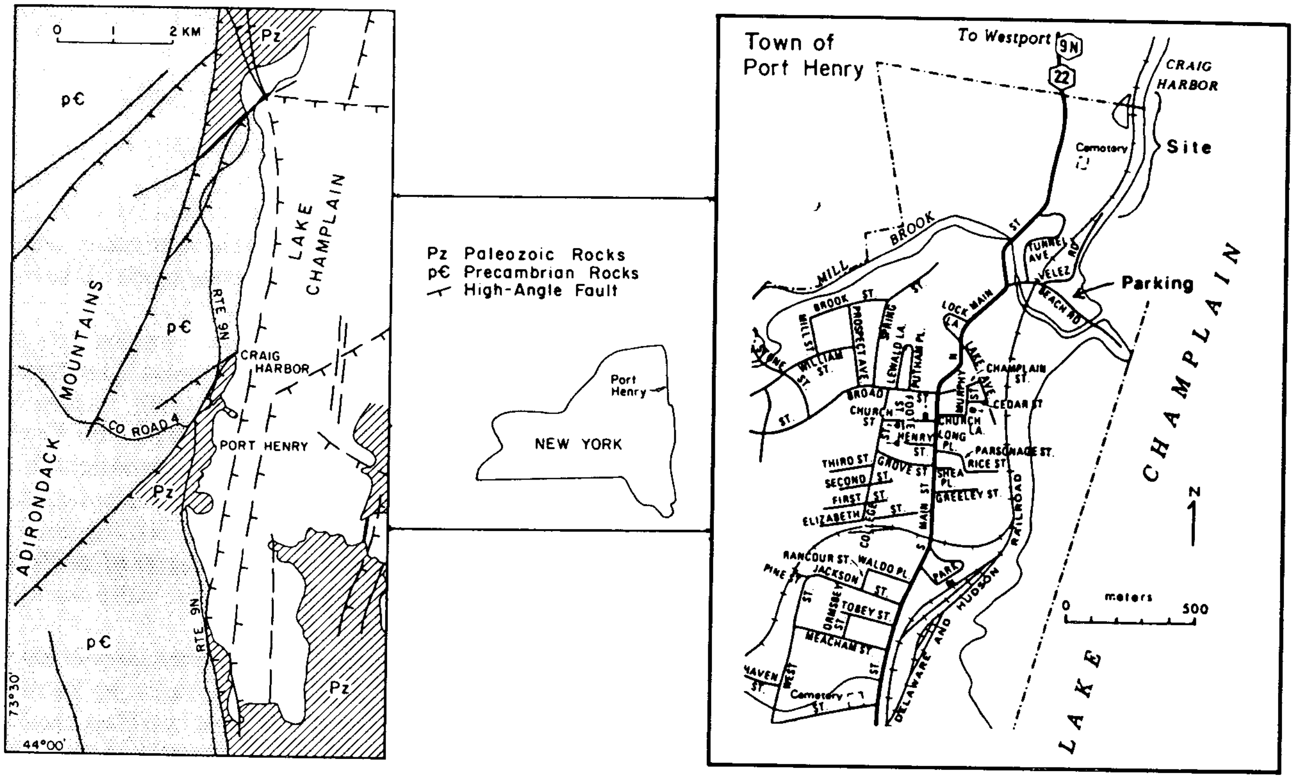

Figure 1. The location of Port Henry, New York and the Craig Harbor site is shown. Geology is generalized from Welby (1961) and Isachsen and Fisher (1971).

exposure contains folded and disrupted lenses of calc-silicate rocks and gneisses (Fig. 2B). Emmons (1842) apparently observed this and other such outcrops in his pioneering 1830s work on the geology of New York. Emmons cited the intrusive form of the marble, its inclusions, and its high-temperature minerals as evidence for an igneous origin of "primitive limestone" (1842, p. 37–59).

The coarsely crystalline, graphite-bearing marbles characterize the Paradox Lake Formation of Walton and DeWaard (1963), suggested as the basal member of a Grenvillian metasedimentary supergroup that overlies older basement paragneisses. Wiener and others (1984) place the marbles above the biotite-quartz-plagioclase Eagle Lake Gneiss, which they assign as the base of the Lake George Group. Charnockitic and granitic gneisses of the Piseco Group make up the older basement rocks that unconformably underlie the Lake George Group (Wiener and others, 1984, p. 22–25). Charnockitic gneiss is the first gneiss unit encountered in the cut north of Craig Harbor.

The granitic gneiss in the cliff face below the marble shows westward-dipping layers of orange-weathering hornblende-rich gneiss and a horizon of magnetite (Fig. 2B), noted in descriptions by Emmons (1842, p. 236–237) and by Kemp and Ruedemann (1910, p. 100–101). Polygonal sheets of gneiss are exfoliating from the cliff wall, but have not yet produced the large talus pile that might be expected from a vertical cliff.

Along the track a few tens of meters north of the harbor, the western wall of the railroad cut exposes the westward-dipping upper contact of metagabbro underlying the hypersthene-bearing, augite, hornblende, microcline, plagioclase gneiss (Fig. 2C). Within a few meters of the contact, the metagabbro is dark, fine-grained granular, and slightly gneissic, with altered plagioclase, brown hornblende, and augite in decreasing order of abundance. Kemp (1894) reported olivine in small amounts in his description of this exposure, but McHone (1971) did not observe olivine in 15 samples taken along this cut. Garnet, apatite, magnetite, and orthopyroxene are present as minor minerals.

To the north and farther below the contact, a coarse ophitic facies of the metagabbro appears. The widespread "Adirondack orange" weathering of the rock surfaces hides the texture except where rock falls and hammer blows have produced fresher, medium gray surfaces. This coarse facies is dominated by coronas of garnet, brown hornblende, biotite, and clear plagioclase surrounding cores of magnetite, augite, or hypersthene. Kemp (1894, 1921) and Gillson and others (1928) carefully documented the corona sequences and spinel clouding of the primary plagioclase, and understood them as metamorphic products. The textures are like those described from other Adirondack metagabbros by Whitney and McLelland (1975) and McLelland and Whitney (1980), who used them to estimate P-T conditions near 8 kb and 800° C (granulite facies). Many small high-angle faults are pres-

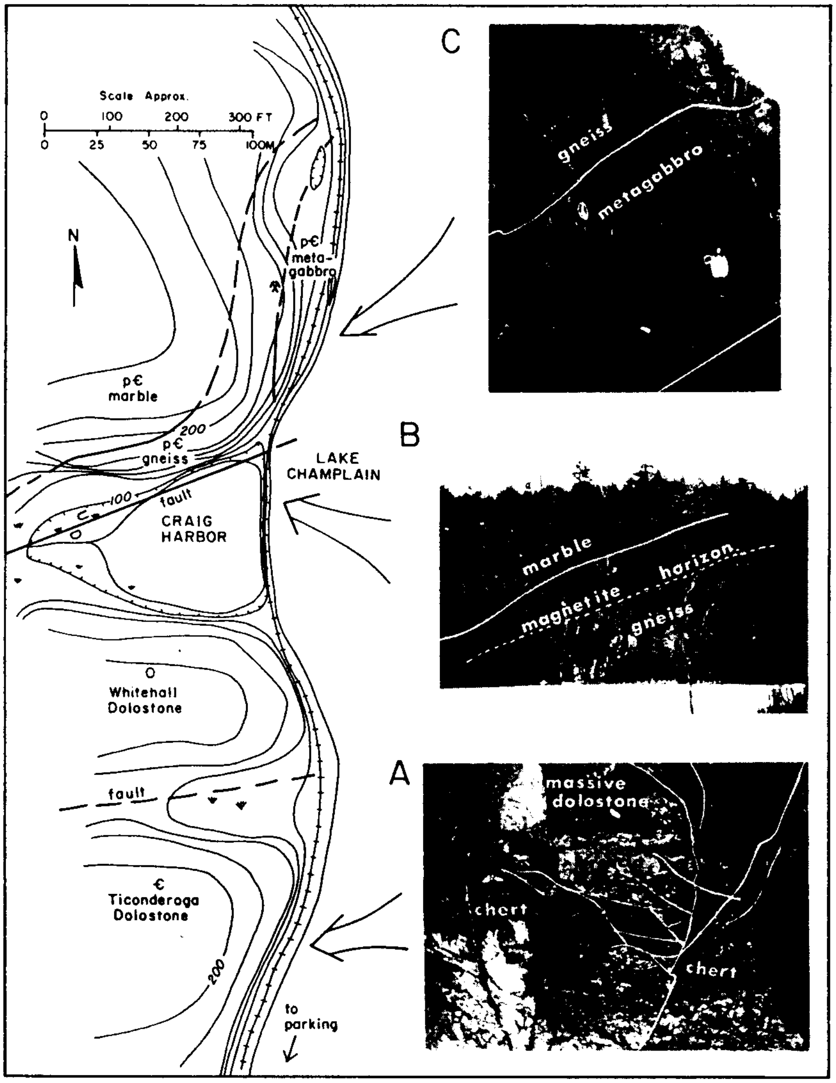

Figure 2. In the geologic sketch map of the Craig Harbor area, topography is only approximate. Photographs have faults and unit contacts emphasized by white lines: A) small fault zone (about 4 × 6 ft; 1.5 × 2 m) in Ticonderoga Dolostone; B) fault scarp on the north side of Craig Harbor, about 165 ft (50 m) high; C) contact of charnockitic gneiss and fine-grained metagabbro, western side of railroad cut about 130 ft (40 m) north of Craig Harbor.

ent in the metagabbro, showing glassy slickensides and zones of breccia with pseudotachylite veins.

In the gneiss above the gabbro, a small tunnel has been excavated into the magnetite horizon (Fig. 2). Although known before the 1840s, this deposit was not worked because the ore is unusually high in sulfur and especially titanium, making it difficult for early forges to handle. Lamellae of ilmenite are exsolved along octahedral crystal planes in polished specimens of magnetite from this prospect (McHone, 1971). Kemp (1898, 1899) and Kemp and Ruedemann (1910) noted the association of magnetite with metagabbro at this site and elsewhere in the region, and advanced a magmatic model for the ore that is similar in some respects to recent ideas for Feiss and others (1983) for the origin of Precambrian magnetite deposits in North Carolina.

Flow-folded marble, calc-silicate skarns, and anorthosite crop out along the railway cuts north of the gabbro. Several high-angle faults with slickensided surfaces are well exposed in the calc-silicate rocks. Garnet, diopside, and wollastonite are present in specimens similar to wollastonite ores mined about 24 mi (40 km) to the north in Willsboro, New York. The Grenville marble has plastically flowed to enclose "xenoliths" of adjacent rocks.

Age of Faulting. The timing of the Adirondack border fault activity is not well established. Because it is likely that much of the border faulting was associated with uplift of the Adirondack dome, the age of fault movement at Craig Harbor has regional significance. Similar high-angle faults are also mapped throughout the Lake Champlain Valley of Vermont and New

York, and extend northward into the St. Lawrence River Valley of Quebec (Quinn, 1933; Welby, 1961; Stanley, 1980).

Quinn (1933) believed that most Lake Champlain Valley faulting preceded Taconic overthrusting, but Welby (1961) showed that many high-angle faults offset the Champlain Thrust of the central Lake Champlain Valley. Snake Mountain, visible to the east of Craig Harbor in Vermont, is an example of a quartzite-capped segment of the Champlain Thrust that is bounded by high-angle faults (Welby, 1961).

Studies of the MacGregor border fault system about 80 km to the south have revealed a history of reactivation that may include movements in Late Precambrian, Paleozoic, and possibly Holocene times (Willems and others, 1983; Isachsen and others, 1983). At least minor Late Mesozoic or younger Lake Champlain Valley fault activity is shown by rare crosscutting relationships with Early Cretaceous alkalic intrusions in Vermont and New York (McHone, 1978; Stanley, 1980; Yngvar Isachsen, personal communication, 1981).

More than 600 ft (200 m) of stratigraphic offset exists on the Craig Harbor fault that postdates Lower Ordovician dolostone. The excellent preservation of the fault scarp and general freshness of slickensides and pseudotachylite in the metagabbro suggests youthful tectonism, an idea also advanced by releveling studies along the Adirondack-Champlain border by Isachsen (1975) and Barnett and Isachsen (1980). As part of this study and to assess the potential for direct radiometric dating, chloritic pseudotachylite collected from a fault breccia in the metagabbro at Craig Harbor was submitted for analysis. The sample yielded a K-Ar date of 665 ± 26 Ma (avg. $^{40}Ar = 0.02661$ ppm; avg. %K = 0.478; $^{40}K = 0.570$ ppm; analysis by Geochron Laboratories, 1984). Because this date precedes the considerable Cambro-Ordovician offset, an unknown amount of argon contamination from the approximately 1000 Ma metagabbro is inferred. Success in future efforts to date the fault movement may require purer rock or mineral material that formed in the fault zone during a single tectonic event.

CONCLUSION

Finally, to quote Ebenezer Emmons (1842, p. 87): "I would take this occasion to recommend to students in geology, to visit the shores of Lake Champlain. It is a field full of interesting and instructive phenomena; one in which the dynamics of geology may be studied to the best advantage. Moreover, the field is quite accessible, and every part may be visited at an expense not disproportionate to the advantages which may be obtained."

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