Ossipee Field Trip Guide
New Hampshire Geological Society

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Introduction

The White Mountain igneous province of New Hampshire is part of the New England-Quebec province of McHone and Butler (1984). In New England this province is represented by two periods of igneous activity: the older between 220-155 Ma and the younger between 130-100 Ma (Fig. 1). Plutons of the older White Mountain series are largely composed of alkali syenites, quartz syenites, and metaluminous and peralkaline granites. Silica-undersaturated rocks (nepheline syenites) have only been found at two localities; Rattlesnake Mountain in Maine and the Red Hill complex in New Hampshire. With the exception of the Belknaps, mafic igneous rocks are conspicuously absent. The largest intrusive complex is the White Mountain batholith which consists of multiple ring dikes intruded into and by composite plutons of metaluminous to peralkaline granite. Peralkaline rhyolites are preserved in several localities.

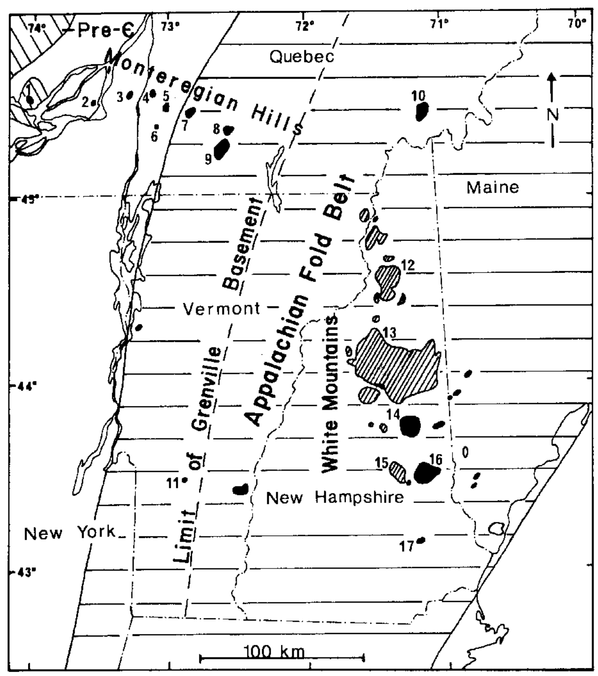

Figure 1. White Mountain and Monteregian Hills igneous provinces. Unfilled plutons emplaced between 220 and 200 Ma; diagonally ruled plutons emplaced between 200 and 155 Ma; filled plutons emplaced between 130 and 100 Ma. Numbered plutons: 1 - Oka, 2 - Mount Royal, 3 - Mount Saint Bruno, 4 - Mount Saint Hilaire, 5 - Mount Rougemont, 6 - Mount Johnson, 7 - Mount Yamaska, 8 - Mount Shefford, 9 - Mount Brome, 10 - Mount Megantic, 11 - Pliny Range, 12 - White Mountain batholith, 13 - Red Hill, 14 - Ossipee, 15 - Cuttingsville, 16 - Belknaps, 17 - Merrymeeting Lake, 18 - Mount Pawtuckaway. LGB - limit of Grenville basement. From Eby (1987).

The Monteregian Hills and younger White Mountain igneous provinces represent the younger period of igneous activity. The bulk of the magmatism occurred *ca.* 125 Ma, but younger ages have been obtained for Little Rattlesnake (114 Ma, Foland and Faul, 1977) and Cuttingsville (100 Ma, Armstrong and Stump, 1971). Plutons emplaced to the west of Logan's line (which roughly parallels the New Hampshire-Vermont border) consist largely of mafic alkaline suites, many of which are nepheline normative. To the east of Logan's line, felsic rocks are much more important components of the intrusions and silica-undersaturated rocks are not found. Some of these younger plutons show ring-like structures (Ossipee and Pawtuckaway) while others appear to be small plugs (e.g. Little Rattlesnake, Ascutney and

Tripyramid). Generally the most evolved rocks are syenites and quartz syenites, but biotite granite (Conway) is found at Ossipee and Merrymeeting Lake. An overview of both provinces can be found in Eby (1987).

The White Mountain igneous province is a classic example of A-type magmatism. Chemically the granitoids plot in the A_1 field of Eby (1992). While mafic rocks are scarce in the older White Mountain series, they are relatively abundant in the younger White Mountain series. Mafic volcanics (basalts and andesites) are exposed in the Ossipee complex and mafic plutonics ranging from pyroxenites to diorites are found at Mount Pawtuckaway. Given the presence of the mafic end members, evolutionary models which yield evolved felsic liquids by differentiation of mafic magmas have proven successful. Particularly in the case of Mount Pawtuckaway, low initial $^{87}Sr/^{86}Sr$ ratios indicate that the magmas were emplaced with little contamination by crustal material.

Ossipee Ring-Dike Complex

Introduction

The Ossipee ring-dike complex of central New Hampshire is a member of the younger White Mountain igneous province. The topography is shown on the 7.5' Tamworth, Ossipee Lake, Melvin Village, and Tuftonboro quadrangles. The complex is circular in plan view and has a diameter of 14 km (Fig. 2). The almost complete outer ring-dike forms a ridge around the inner basin on the eastern side and forms the outer slopes of the high hills in the western part of the complex. The western third of the complex has a rugged topography and is underlain by basalts and rhyolites. The eastern portion is an interior basin underlain by granite. Maximum relief is approximately 750 m. Ossipee has played a central role in models dealing with the origin of ring dikes (Billings, 1943, 1945; Chapman, 1976) and has long been considered a classic example of a ring-dike complex.

The bedrock geology of the Ossipee complex was originally mapped by Kingsley (1931). Portions of the Ossipee complex appear on the geologic maps for the Mt. Chocorua (Smith et al., 1939), Winnipesaukee (Quinn, 1941), Wolfeboro (Quinn, 1953), and Ossipee Lake (Wilson, 1969) quadrangles. With the exception of the Ossipee Lake quadrangle the geology was based on the original work of Kingsley (1931). The intrusion was remapped by Carr (1980), and his thesis is the basis for the geologic map of the Ossipee complex (Fig. 2) and much of the ensuing discussion of the geology and petrography of the complex.

General Geology

The Ossipee complex occurs within the Merrimack synclinorium and intrudes the Early Devonian calc-alkaline Winnipesaukee tonalite, the Lower Devonian Littleton Formation and the Pennsylvanian/Mississipian two mica granite of the Sebago batholith and Effingham pluton. The outer margin is an almost complete ring-dike with multiple intrusive phases. Much of the ring-dike consists of medium to coarse-grained quartz syenite, but locally pink granite and/or porphyritic rhyolite are important components. The ring-dike is almost vertical, but slightly inward and slightly outward dips have been recorded. The complex is unique in the Younger White Mountain igneous province for the large amount of preserved basalt. The basalts generally occur as inward dipping blocks in the rhyolite. In places thick basalt-rhyolite sequences, which were apparently contiguous, have been preserved, thus suggesting that some of the basaltic and rhyolitic volcanism was contemporaneous.

A sequence of thinly laminated beds of andesitic and basaltic ash, with shallow to moderate inward dips, occurs along the northeastern margin of the complex. The ash beds are interpreted to be caldera-type lake-bed deposits. Multiple phases of rhyolite have been identified, and on the basis of groundmass grain size it is believed that much of the rhyolite was subvolcanic (hence the name "intrusive" rhyolite). Some of the rhyolite, however, was erupted. The eastern portion of the complex is underlain by pink coarse-grained "Conway" granite. The granite is poorly exposed except at the tops of hills within the interior basin, where rounded and deeply weathered outcrops can be found. Gravity and magnetic data (Sharp and Simmons, 1978) indicate that the complex has a vertical core of mafic rock with a thin granitic carapace. In areas marked by maximum gravity or magnetic anomalies gabbroic and dioritic enclaves can be found in the granite.

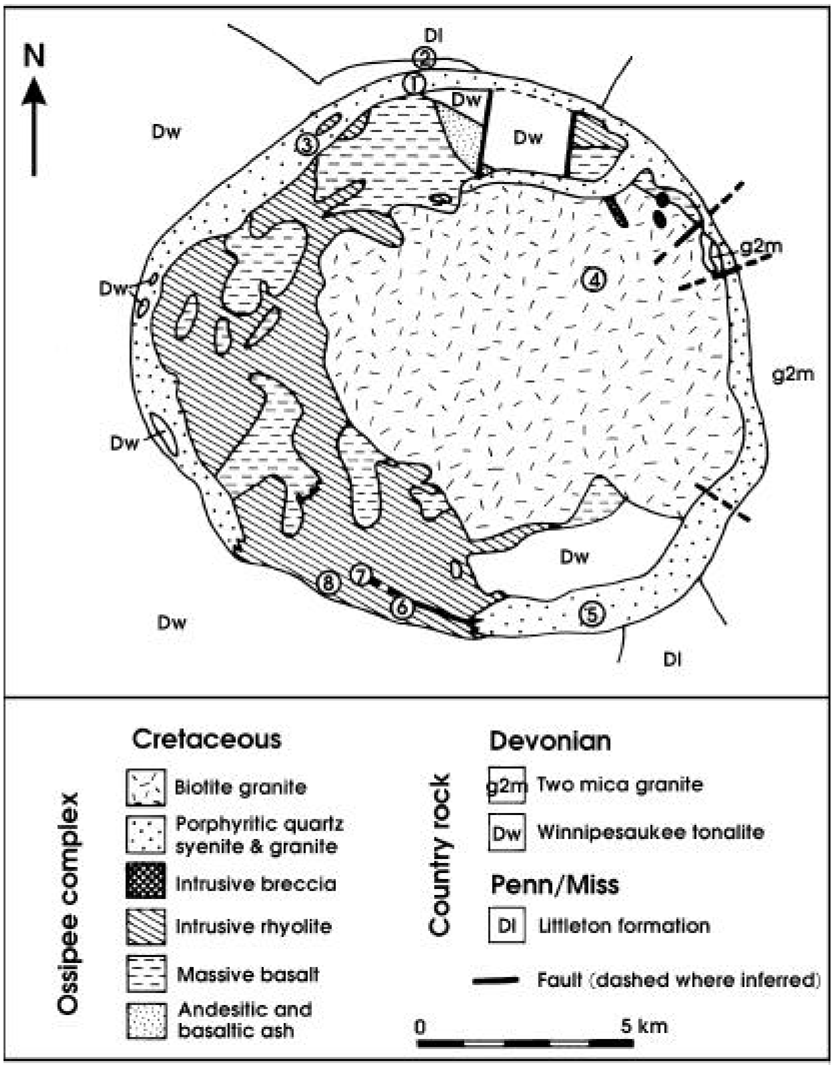

Figure 2: Geologic map of the Ossipee complex modified from Carr (1980). Numbers indicate the locations of the field trip stops.

Carr (1980) proposed the following sequence of events for the Ossipee complex. (1) Eruption of basaltic and andesitic magmas from a hypabyssal magma chamber forming ash and flows. (2) Intrusion of basaltic magmas through the volcanic pile forming massive basalts. (3) Rapid intrusion of rhyolitic magmas along dikes disrupting the pile of pre-existing ash and massive basalts and causing the collapse of the pile into the felsic magma. The presence of xenocrystic fragments of quartz and alkali feldspar, and the existence of intrusive breccia pipes with rhyolitic matrix, suggest that this may have been an episode of explosive magmatism. (4) Formation of the outer ring fractures and cauldron subsidence. (5) Emplacement of biotite granite. Since this granite occurs as a sheet above the mafic plug, which may represent the earlier basalt magma chamber, it was suggested that the granitic magma may have been emplaced along a cauldron fracture formed above the earlier magma chamber. (6) Emplacement of "lamprophyric" (basaltic) dikes.

Lithologic Descriptions

Mafic Units

Andesitic and basaltic ash **-** ash beds vary in thickness from 1 mm to tens of cms and vary in color from light gray to black. Many of the beds are finely laminated and graded. Identifiable minerals are plagioclase fragments, interstitial brown biotite and magnetite, and tiny euhedral apatites.

Basalt **-** two lithologies have been distinguished, one is coarsely porphyritic and the other is massive and sparsely- to non-porphyritic. Plagioclase is the dominant phenocryst phase and varies from 0.1 to 0.5 cm in size in the sparsely prorphyritic variety and up to 1 cm in size in the coarsely porphyritic variety. Rare phenocrysts of altered clinopyroxene and biotite have been observed. The groundmass consists of plagioclase, altered clinopyroxene, amphibole, bitotite and magnetite. Some specimens are strongly magnetic. Extensive replacement of plagioclase by epidote has been observed in some specimens.

Felsic Units

Rhyolite - all the rhyolites are mineralogically similar. Phenocrysts are angular to sub-angular alkali feldspar fragments and sub-rounded and embayed euhedral quartz grains. Rare plagioclase and amphibole fragments have been noted. The groundmass consists of quartz, K-feldspar, minor plagioclase, amphibole, and biotite. Basaltic and dioritic enclaves are common in the rhyolites. Hornblende syenite enclaves have also been observed. Many outcrops show a flow foliation. Texturally five varieties of rhyolite have been distinguished: (1) small pink alkali feldspar and clear quartz phenocrysts in a dense, black, very fine-grained matrix; (2) cream colored alkali feldspar and gray smoky quartz phenocrysts in a fine- to very-fine-grained dark gray matrix; (3) large pink alkali feldspar and gray smoky quartz phenocrysts in a fine-grained light brown matrix; (4) small cream colored alkali feldspar and gray smoky quartz phenocrysts in a medium- to fine-grained light brownish-gray matrix; and (5) large euhedral to subhedral phenocrysts of pink alkali feldspar and gray quartz in a fine-grained light brown to blue-gray matrix which shows spherulitic textures in thin section.

Porphyritic quartz syenite - alkali feldspar and sparse quartz phenocrysts occur in a medium- to fine-grained groundmass of alkali feldspar, quartz, biotite, hornblende and accessory magnetite, ilmenite and apatite and trace zircon. The quartz phenocrysts are partially resorbed by the groundmass minerals. The bulk of the quartz syenite is gray in color, but a somewhat finer grained pink variety has been observed. The groundmass of the pink variety contains abundant quench (graphic) textures. Hornblende syenite and basalt enclaves are found in the porphyritic syenite.

Subporphyritic granite - subporphyritic, medium- to fine-grained granite, pink on fresh surfaces, consisting of quartz, alkali feldspar, minor oligoclase and biotite (often altered to chlorite). A characteristic feature is the intergrowth of quartz and alkali feldspar (graphic texture) in the finer-grained groundmass. Basalt enclaves are occasionally observed. The subporphytitic granite and the porphyritic quartz syenite are the two major lithologies of the ring dike.

Biotite granite - medium- to coarse-grained, phaneritic to subporphyritic, pink granite. Early maps of the Ossipee complex identified this granite as "Conway" (because of its pink color), but it is clearly not correlative with the Conway granite of the White Mountain batholith. Mineralogically the rock consists of rounded gray quartz, buff-colored alkali feldspar, minor plagioclase and biotite, and rare amphibole. The accessory minerals are fluorite, allanite, zircon, apatite, and opaque oxides. In the subporphyritic varieties quartz and alkali feldspar form the phenocrysts. Miarolitic cavities are locally common and often contain orthoclase and smoky quartz crystals up to 3 cm long. In many localities the granite is cut by pink to buff colored, fine-grained aplite dikes which are mineralogically similar to the granite. The dikes are usually less then 5 cm wide and show no preferred orientation.

Road Log and Stop Descriptions

The first stop is on the south side of Rt. 25 at the entrance (opposite Rt. 113) to the Chocorua Valley Lumber yard. Depending on your route into the Ossipee area this stop is either 19.8 miles northeast of the juncture, in Meredith, of Rts. 3 and 25 or 3.8 miles west of the juncture of Rts. 16 and 25. At the first stop set your odometer to 0.

STOP 1: Granitic facies of the ring-dike

Good outcrops of pink fine- to medium-grained subporphyritic granite are exposed along the access road leading to the lumber yard. The Rt. 25 road cut slightly east of this site exposes the same lithology. In thin section this rock has a finer-grained matrix with graphic intergrowths indicative of rapid cooling. Sparse, partly digested, basaltic enclaves are found in this unit. This granitic facies is just outward of the porphyritic quartz syenite which forms the bulk of the ring dike, and it is apparently part of the ring dike. Somewhat similar, but not as quartz-rich, rocks comprise the ring dike in the southwest corner of the Ossipee complex. Contacts have not been observed between this granitic phase and the quartz syenite porphyry.

From the lumber yard stop go north on Rt. 113 (directly opposite lumber yard) 0.3 miles. The outcrops are located in the river to the north (left side) of the road.

STOP 2: River outcrop of Winnipesaukee Tonalite (?)

According to the new New Hamsphire bedrock geologic map (Lyons et al., 1997) we are in the Winnipesaukee tonalite. This is a delightfully complicated outcrop which should provoke a great deal of discussion. Hopefully the discussion won't be too heated. On a warm summer day this is a cool spot, so there will be ample opportunity for a cooling-off time. A coarse-grained quartz-feldspar rock that appears to be a pegmatite pod is located along the river bank. This lithology is apparently intruded by a medium-fine-grained, gray granite that contains metamorphic enclaves (Littleton?). The granite is cut by pegmatitic and aplitic dikes. A mafic dike, perhaps related to the Ossipee complex, cuts all of the other units.

Return to Rt. 25 and turn right (west). Continue on Rt. 25 to a road entrance marked by a flashing yellow light (2.2 miles at South Tamworth). Park by the side of the road or on a small road leading diagonally off to the northwest.

STOP 3: Porphyritic quartz syenite, basalt, rhyolite, and dikes-Cold Brook traverse

On the north side of the road the Winnipesaukee tonalite is exposed in the Cold Brook. These outcrops are cut by several mafic dikes. Return to the road and proceed south up the Cold Brook. Virtually everyone who has mapped in the Ossipees has described the Cold Brook section, and none of the descriptions are the same. Here's your chance to add additional opinions. The first outcrops encountered in the brook consist of what appears to be a large block of the granitic facies of the ring-dike, with numerous basaltic enclaves, immersed in basalt. Blocks of layered intrusive rhyolite are also found in the basalt. The host basalt is massive and contains enclaves of porphyritic basalt with plagioclase phenocrysts. Chemically the host basalt is more alkali rich then the common basalts of the Ossipee complex. Continuing up the Cold Brook the next set of outcrops form a mini gorge in the brook and consist of porphyritic quartz syenite. Large alkali feldspar and quartz phenocrysts occur in a fine-grained matrix, which in thin section has graphic intergrowths indicating rapid cooling. The quartz grains have resorption rims of alkali feldspar indicating a drop in water pressure. At this point you have two choices. You can either continue up the Cold Brook to the road crossing or return to your vehicle and drive south up the road that parallels the west side of the Cold Brook to the road crossing. The latter choice is probably the easier one. At the road crossing basalt and rhyolite outcrops are encountered in the brook. The basalts are generally massive, but locally they are coarsely porphyritic with abundant plagioclase phenocrysts. Much of the plagioclase has been replaced by epidote giving the rock a greenish cast. Intrusive rhyolites, rhyolitic breccias, and rhyolites with eutaxitic textures are exposed in this section from just below the road crossing to about 100 m above the road crossing. These textures are best viewed from the bridge looking down on the outcrops.

Return to vehicle and drive east on Rt. 25 to juncture of Rt. 25 and 16 (7.6 miles). Turn right (south) onto Rt. 16. At 10.2 miles turn right (west) onto Pine Hill Road. At 13.5 miles there is a road to the right (north). Park at this intersection.

STOP 4: "Conway Granite" and aplite boulders stop

The "Conway Granite" is poorly exposed and most outcrops, which are found at or near the tops of hills, are rounded and deeply weathered. At this location construction of a road for a failed development has exposed a number of fresh boulders of the Conway Granite. These boulders show the range of textures and mineral compositions which have been found in the field. A number of the boulders have aplitic layers which are a relatively common feature of the "Conway Granite".

Return to vehicle and continue west on Pine Hill Road. At 13.7 miles turn left onto Connor Pond Road. Turn right (south) onto Ossipee Mtn. Road (15.0 miles). In Moultonville (16.4 miles) turn left (east) to Center Ossipee. Just before railroad tracks (17.3 miles) turn right (south) onto Chickville Road. Continue on to Tuftonboro (24.0 miles) and turn right (west) onto Rt. 171. Continue for another 0.7 miles (24.7 miles) to a road marked Sentinel Lodge. Turn right (north) and proceed 1.0 mile to the top of the ridge (25.7 miles). Turn right (east) onto Sentinel Baptist camp road and go 0.2 miles to a trail on the right side of the road labeled "Ledge" (25.9 miles).

STOP 5: Intrusive rhyolite

Follow the trail to the end (approximately 0.3 miles) where you will find a large cliff face of intrusive rhyolite. Numerous basalt blocks and enclaves are found in the rhyolite along the trail before the ledge. A variety of basaltic enclaves are found in the intrusive rhyolite exposed on the cliff face.

Return to the intersection of Sentinel Lodge road and Rt. 171 (27.1 miles). Turn right (west) onto Rt. 171. At 30.3 miles jeep trail departs on the right side of the road. Park along side of road. Proceed north on the jeep trail.

STOP 6: Porphyritic quartz syenite, rhyolite, and basalt-Hunter Brook traverse

Follow the jeep trail until it comes to Hunter Brook (approximately 500 m). Porphyritic quartz syenite outcrops is the stream bed. Proceed up Hunters Brook. The outcrop at the beginning of this section is very weathered but in the upstream direction the outcrop becomes fresher. The next unit encountered is intrusive rhyolite and the change from porphyritic quartz syenite to intrusive rhyolite seems to be gradational over a relatively short distance. Continue up stream to outcrops of massive basalt. The abundance of phenocrysts is quite variable, and most phenocrysts are less than 0.2 cm in size. At the upper end of this section a contact with fine-grained rhyolite is exposed. The contact dips steeply inward and there is evidence of shearing. The phenocrysts in the basalt increase in both size and number as the contact is approached.

Return to vehicle and continue west on Rt. 171. At 32.7 miles turn right (north) into the "Castle-in-the-Clouds" entrance road. There is an admission fee which at the time this field guide was written was $4.00/person. There are several points of interest on the entrance road, but the actual field trip stop is at the visitors center. These additional points of interest are described below.

At 33.0 miles there is a parking area for a waterfalls. Walk in 200 m to the falls. Intrusive rhyolite is exposed at the falls and in the brook. The rhyolite contains numerous blocks of basalt with abundant small plagioclase phenocrysts.

At 34.1 miles there is a scenic view point to the left of the road with good exposures of intrusive rhyolite. Outcrops at the base of the lookout platform contain a variety of enclaves: basalt with abundant small phenocrysts, basalt with sparse phenocrysts, phenocryst-free basalt which has been converted to a hornfels, and rare fine-grained and coarse-grained diorite inclusions.

At 34.4 miles park in the Castle-in-the-clouds parking lot and walk to visitors center. Facilities in the center include restrooms and a snack bar. The field trip stop is the patio of the visitors center.

STOP 7: Intrusive rhyolite with abundant enclaves

The wall of the patio is constructed of intrusive rhyolite. A wide variety of enclaves can be found in the wall. NO HAMMERS! If time and the tram drivers permit, there are excellent exposures of intrusive rhyolite on the road which leads from the visitors center to the "Castle".

Return to vehicle and exit from Castle-in-the-Clouds. At 35.3 miles, after you have passed through the exit gate, stop at the outcrop on the right (west) side of the road. This is a blind curve so park well down the hill from the curve and be on the lookout for vehicles. While there isn't much traffic the road is narrow. If you skipped Stop 7, you can reach Stop 8 by proceeding west on Rt. 25 from the entrance to Castle-in-the-Clouds. A road to your right (north) is signed Castle-in-the-Clouds service road and bottling plant. Drive up (north) this road to the outcrop which is exposed in a road cut on the left (west) side of the road.

STOP 8: Intrusive rhyolite and ring-dike

Porphyritic quartz syenite is not found in this region and the intrusive rhyolite occupies the apparent position of the ring-dike. This outcrop shows multiple phases of intrusion. Fine-grained rhyolite, which contains blocks of massive basalt, crops out at the lower end of the outcrop. In the uphill direction there is an abrupt change to a very porphyritic facies of the rhyolite. The fine-grained rhyolite may actually be a large block in the porphyritic variety.

Return to vehicle. At 36.2 miles the service road intersects Rt. 171. End of Ossipee field trip.

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