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Selected abstracts from unpublished notes and manuscripts of Clifford A. Kaye.

by

Byron Stone (editor)[1]

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This report is preliminary and has not been review for for conformity with U.S. Geological Survey editorial standards (and stratigraphic nomenclature).

[1]USGS, Reston, Virginia

Table of Contents

The Brewster Island Sill-Swarm of Layered Olivine Diabase

The Brewster Islands are a group of nine islands and a number of rocks and shoals forming a U-shaped chain just east of Boston harbor. They are composed mainly of two long sills as olivine diabase intruded into argillite, and about a dozen or so lesser sills. The Great Sill forms the inner islands and is about 100 meters thick. The Lesser Sill is about 60 meters thick and forms the outer islands. The sills generally conform to the structure of the Brewster Syncline, but also have many minor undulations and folds. Faults cut across the sills, as seen by displacements between islands in the chain. The base of the Great Sill is a chilled contact consisting of 1 meter of black basalt overlain by 1 to 4 meters of light green olivine-rich rock (picrite). Layered light gray, coarse-grained and dark gray, fine-grained diabase comprise the body of the sill. Pairs of layers vary from 6 to 25 cm. Petrographic analysis reveals the diabase is mainly plagioclase laths (labradorite to oligoclase), pyroxene (diopside and augite) and a light greenish uralitic amphibole similar to hornblende. Olivine occurs at the base of dark, fine-grained layers. The Lesser Sill on Little Brewester Island is unlayered and consists of alternating diabase and argillite. Similar layered intrusions have been studied in Montana and Greenland. The layering occurs in a slowly cooling magma where crystals settle out diffentially by gravity. The Medford Gabbro is similar mineralogically to the Brewster sills but is not layered. The Nahant Gabbro, however, is layered and has been intruded into the axis of the Charles River Syncline, similar to the intrusion into the Brewster Syncline. Biotite in the Nahant Gabbro has been dated as Lower to Middle Ordovician. Both intrusions may have occurred during plate collisions at that time.

Charles River Syncline

The east-west trending Charles River Syncline is a broad structure whose northern limb extends from the Charles River to the Northern Boundary Fault. Its axis in the City Tunnel Extension is 500 m wide but to the east it becomes "V" shaped. It is assumed to pass down the middle of the argillite belt, flanked on the north and south by the Brighton Formation. The syncline appears to be flat-floored, without an eastward plunge typical of other folds in the area. Exposure of the Weymouth Formation in Nahant is the only evidence of closure of the syncline. This could be due to a northeast plunge or an angular unconformity in this area.

Folding: North Side of Charles River Syncline

Bedrock in the Cambridge-Somerville area contains various small folds superimposed on the larger synclinal structure. These can be seen in outcrops and in tunnel maps. Typical amplitudes are 0.5 Km from crest to crest. A sizeable arch-shaped fold was also exposed in the new MBTA Red Line tunnel that was not seen in the nearby City Tunnel Extension.

Isoclinal Folding

Surface outcrops are inadequate to determine the presence of large-scale isoclinal folding. Geologic maps of bedrock tunnels in Boston show evidence of these structures but do not identify them directly. Isoclinal folding is one explanation for the geologic disparities between surface outcrops and bedrock mapping in the Dorchester Tunnel. Many shallow folds are visible in the massive conglomerates of Roxbury, Brookline and Newton. Mapping of the Red Line tunnel showed excellent graded bedding both right side up and upside down. This led to the interpretation that a large recumbent isoclinal anticline, overturned to the north, has been arched into the Porter Square anticline which is cut by diked faults. Additional mapping in the Harvard Square area indicates that argillite in the City Tunnel Extension also probably contains tight folds that are overturned to the north but not recumbent.

Mega Kink Bands

Two elongate, structurally discordant bands of argillite, each about 1.5 km wide and 9 km long originated from the Mystic Lakes area in Arlington, Mass. These bands contain strike trends noticeably different than the prevailing east-west to east-northeast trends of the adjacent argillites. They are designated kink bands due to their similarity to smaller scale structures seen in foliated rocks and deformed minerals. These kink bands are interpreted from fragmentary data from outcrops, borings and tunnel exposures. The northern one, named the Malden kink band, consists of beds that strike northeast and dip southeast. It follows the south side of the northern Boundary Fault northeastward to Lynn. The southern band, named the Somerville kink band, passes east-southeast through Medford and Somerville and contains beds striking N63°W and dip southeast 7° to 70°. These bands may be the result of eastward movement of basement rock lying between them. The discordant alignments are thought to be caused by drag as the relatively thin skin of argillite separated, at least in part, from the underlying eastward moving block.

Nature of Folding of the Boston Basin

Historically, the nature of the folding of the Boston Basin has been difficult to assess due to lack of outcrops. A relatively simple concept of large, open folds has been accepted. However, upside down, graded bedding recently discovered in the subway tunnel under Massachusetts Avenue in Cambridge indicates the presence of isoclinal recumbent folds. This concept applied to mapping around Harvard University reveals a complex fold system with several recumbent isoclinal folds. This interpretation also fits data from outcrops in Mattapan, Hingham, Hull and the Harbor Islands.

Origin of Xenoliths

Ultramafic xenoliths found in a series of NNE trending dikes in the Boston area are of deep-seated origin. They are unlike any surface rocks found in the area today. They contain high pressure garnet, graphite, and large pink feldspars that point to deep crustal or subcrustal origin and slow cooling. The mesostasis of these dikes is glassy and indicates rapid cooling. Two stages of solidification may have occurred: 1) opening of deep-seated fractures creating magma chambers, and 2) rapid closing of these fractures forcing magma upwards. Lampophyre and xenolithic dikes in Cambridge, Somerville and Malden form a narrow, straight band trending N15°E. This band lines up with an elongate, sheared body of serpentinite in Lynnfield and a basin of Triassic red beds farther north in Middleton. These structures may all be related to changes in crustal stresses caused by plate tectonics in middle to late Mesozoic time. Deep magma chambers could have formed during opening of the proto-Atlantic Ocean and were closed later during subduction of oceanic plates. If so, then the age date of 202 x 10^6 years obtained from a xenolithic dike in the Porter Square Station is too old.

Red Beds

The existence of red beds of limited extent on the north and south sides of the Boston Basin is known from pebbles in the glacial till, a few borings, and one outcrop that no longer exists. Occurrences in the north include till pebbles on Outer Nahant, rock cores along Lynn Harbor, and pebbles from drumlins in Revere, Winthrop and Deer Island. The lithology is dark red sandstones and mudstones. In the northern belt, red beds are interbedded with light pink arkose and arkosic quartzite. Some red bed pebbles contain nodules of very finely crystalline, non-fossiliferous limestone. These are similar to nodules in the Weymouth Formation which contains lower Cambrian fossils.

In the southern belt, red bed pebbles have been found in glacial till on Mt. Ararat and in drumlins on Houghs Neck and Hingham Bay. Red sandstone was found in a boring north of Nut Island. A boring on the west end of nearby Peddocks Island showed graywacke with thin beds of red shale. In both areas the red beds appear to be of limited extent and to grade laterally east and west into similar non-red sediments.

Stony Brook Fault to Ashmont

This area shows the complex relationship between the Mattapan rhyolites, the Neponset meta-andesites, and the sediments that grade laterally into them and unconformably overlie them. The Mettapan rhyolite consists of zones of flow breccia, explosion breccia, massive tuff, thinly bedded tuff, ash flows and laminated welded tuff. They are predominantly white in color due to secondary kaolinite. Outcrops occur west of Mattapan Square around Sally Rock. Volcanogenetic sediments (rhyolitic sandstone and volcanic conglomerate) interfinger with and overlie the rhyolites. The sediments are in turn overlain by dark andesites that also grade laterally and vertically into volcanogenetic sediments. Unconformities and facies changes complicate the sequence. Good exposures can be found between Mt. Hope Cemetary and the new Mattapan School and in Milton on Blue Hill Avenue about 1 km south of the Neponset River bridge. Outcrops around Mattapan Square show how laminated pink welded tuff is in contact with dark greenish gray volcanics to the north, thin-bedded white crystalline tuff to the south and dark volcanics again to the east. A similar relationship was seen in the Dorchester Tunnel. Dark volcanics are limited in extent and pinch out to the east due to an unconformity with overlying sediments of the Neponset River. The unconformity is well exposed in outcrops along the Conrail tracks (327, 125E/9, 681, 860N). Argillite is underlain by patches of conglomerate underlain by volcanics (andesite, rhyolite, andesite) then patches of sedimentary rock and finally rhyolite that ties into Mattapan Square exposures. At least 5 unconformities exist. The irregular surfaces of these unconformities may explain some features previously seen as faults. Folding in this area is tight, small-scale and oriented in various directions. Folding in the overlying sediments appear to be discordant from the underlying volcanic material. A spine of volcanic rock extends from Cookson Terrace to Ashmont containing flow bending that dips steeply north. This may be a tight isoclinal fold overturned to the south.

Strike Domains

The Boston Basin can be divided into several areas, or domains, each having a characteristic strike or structural trend and bounded by faults or other features. The N78°E strike domain is dominant onshore. Offshore, this trend changes to approximately N45°E in the northern portion of the Basin. To the South, data from seismic surveys, outcrop mapping and bedrock topography indicate the onshore N78° domain continues offshore for at least several kilometers east of Nantasket.

Subway Tunnel in Cambridge and Somerville (Red Line Extension)

Bedrock was excavated for two parallel tunnels 6.75 m in diameter and two underground stations at Porter Square in Cambridge and Davis Square in Somerville. The tunnels cross two distinct geologic terrains separated by a large near-vertical fault about 30 meters north of Wendell Street. South of the fault the rocks are dominantly pyroclastics, composed of tuffs, tuffaceous argillites and arenites. These are intruded by many chloritized keratophyric dikes. The structure is highly faulted and folded. Most of the folds are isoclinal, overturned to the northeast with a northwesterly strike. Soft-rock alteration is widespread and extends to about 15 meters below the bedrock surface. The Wendell Street fault is a zone about 55 meters wide consisting of mylonitized argillite to the north and sandy cataclasite to the south. The fault dips north at about 80°. Bedrock north of the fault is stratified argillite with only local soft rock alteration associated with dikes. Dikes and sills of at least three rock types are present, many along earlier faults.

The bedrock is folded into an east-west trending anticline through Porter Square. Inverted graded bedding in one area indicated a recumbent isoclinal fold overturned to the north and superimposed on the anticline. This fold indicates that the structure of the argillites is far more complex than previously thought.

Triassic Basin

A basin of red beds, here named the Ipswich River Basin, has been found beneath glacial drift in a quarry in Peabody, Mass. The basin, probably related to the Newark group of Late Triassic to Jurassic age, had been suspected earlier from Triassic-like pebbles in the drift. The red beds are exposed in the north end of the quarry and consist of fine to coarse grained arkose, poorly sorted conglomerate, highly micaceous sandstone, siltstone and fissile shale. Pebbles and cobbles in the conglomerate are well-rounded to subangular and up to 60 cm in size. Some are recognizable granites from the surrounding Paleozoic terraine. As exposed in the quarry, the basin is surrounded by cataclastic rock consisting of ultramylonite, altered diorite, pseudotachylite, and phylonites. The contact is a sharp, planar fault striking N40°E and dipping 65°NW, the same as bedding in the red beds. The fault contains clay gouge 2-3 cm thick above which the red beds are brecciated for a thickness of 1.5 m. Aeromagnetic evidence indicates the basin may be about 6 km long and trend to the northeast from the quarry. The discovery raises the possibility that other red bed basins may exist beneath drift in New England. It also show the existence of Mesozoic faulting in the region.