U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division

Saugus Iron Works National Historic Site

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Saugus Iron Works National Historic Site

sair_geology.pdf

Version: 9/27/2011

Geologic Resources Inventory Map Document for Saugus Iron Works National Historic Site

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Geologic Resources Inventory Map Document

Saugus Iron Works National Historic Site, Massachusetts

Document to Accompany Digital Geologic-GIS Data

sair_geology.pdf

Version: 9/27/2011

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Saugus Iron Works National Historic Site, Massachusetts (SAIR).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

National Park Service (NPS) Geologic Resources Inventory (GRI) Program staff have assembled the digital geologic-GIS data that accompanies this document.

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About the NPS Geologic Resources Inventory Program

Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the Earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

Products

Scoping Meetings: These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

Digital Geologic Maps: Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm

Geologic Reports: Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage http://www.nature.nps.gov/geology/inventory/gre_publications.cfm

GRI geologic-GIS data is also available online at the NPS Data Store Search Application: http://irma.nps.gov/App/Reference/Search. To find GRI data for a specific park or parks select the appropriate park

(s), enter “GRI” as a Search Text term, and then select the Search Button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: http://www.nature.nps.gov/geology/inventory, or contact:

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The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division.

Map Unit List

The geologic units present in the digital geologic-GIS data produced for Saugus Iron Works National Historic Site, Massachusetts (SAIR) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., ZJ(?)db - Diabase dike with magnetite). Units are listed from youngest to oldest. Information about each geologic unit is also presented in the Geologic Unit Information (UNIT) table included with the GRI geology-GIS data.

Geologic Map Units

Proterozoic? To Jurassic?
ZJ(?)db (Diabase dike with magnetite)

Devonian
Dpgr (Peabody Granite)
Dpgrb (Peabody Granite, brecciated)

Proterozoic to Devonian
ZDd (Quartz-diorite and diorite)
ZDgdta (Aplitic granodiorite)
ZDgdt (Tonalite to granodiorite)
ZDgdtfb (Tonalite to granodiorite, fault breccia)

NeoProterozoic to Lower Cambrian

Boston Bay Group
ZCrcca (Roxbury Conglomerate and Cambridge Argillite, undifferentiated)
ZCrsca (Argillacious sandstone and siltstone and Cambridge Argillite, undifferentiated)

NeoProterozoic
Zvk (Quartz keratophyre and keratophyre)
Zlv (Lynn Volcanics)
Zlvfb (Lynn Volcanics, fault breccia)

Proterozoic
Zqo (Quartzite and Olistostromal Assemblage)
Zmu (Mafic metavolcanic xenoliths of unknown affinity)
Zgrt (Trondhjemite)
Zgmd (Granodiorite to quartz monzonite)
Zgr (Granitoidal rocks, undifferentiated)

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below.

ZJ(?)db - Diabase dike with magnetite (Proterozoic? to Jurassic?)

(description modified from Kaye, 1980)

This rock is fine- to medium-grained, black to medium-gray, light-brown on weathered surfaces. Abundant scattered magnetite crystals give the rock a sandy texture to the touch. Weathered surfaces commonly exhibit strong erratic magnetic polarization, probably caused by lightning strikes. Dikes are mostly oriented east-west; a smaller set trends north-south.

Similar dikes occur throughout eastern Massachusetts (Kopera, field observations, 2003-present). Their age is largely presumed to be Mesozoic, however, many, upon detailed investigation, are Proterozoic through Devonian in relative age (see discussion for ZDd below). Kaye (1980) does not discuss relative age relations for the Zj(?)Db in the vicinity of SAIR, however, the rock may be related to Ordivican-and-older age mafic intrusives at Nahant (Thompson et al., 2010), and/or doleritic rocks of Proteroizoic age that intrude the Boston Bay Group at Nahant and on the Boston Harbor Islands (Ross and Bailey, 2001; Thompson et al., 2011). *GRI Source Map ID 75579* (Preliminary SAIR Report)

Dpgr - Peabody Granite (Devonian)

Includes unit: **Dpgrb** - Peabody Granite, brecciated (Devonian)

(description from Kaye, 1980)

Alkali granite. Coarse-grained, light greenish gray. Perthitic orthoclase, 45-55% by volume; quartz, 42-53%; aegirinaugite, 2-5%; and riebeckite, trace. Slight to no secondary alteration of orthoclase; quartz shows little strain shadow. Texture is xenomorphic granular with sutured grain boundaries and poikilitic grain intergrowths.

AGE: 378.08 +/ - 0.62 Ma (U/Pb; Thompson and Ramezani, 2008), 395+/-2 Ma (U/Pb; Zartman, 1977). *GRI Source Map ID 75579* (Preliminary SAIR Report)

ZDd - Quartz-diorite and diorite (Proterozoic to Devonian)

(description modified from Kaye, 1980)

Fine- to medium-grained, dark-gray to black in color. Shiny black biotite generally clearly visible to the unaided eye. The rock primarily consists of albite (mostly untwinned stubby crystals), quartz, orthoclase, biotite, homblende, diopside, apatite, and ilmenite. Dark minerals make up about 50% by volume. Xenomorphic granular with poikilitic crystal arrangement and myrmekitic clots. Secondary alteration is slight to nil. In many places rock is complexly injected or soaked by red alkali-feldspar granite and pegmatite.

AGE AND REGIONAL CORRELATIONS: Many, if not all, diorites and gabbroic intrusive rocks in northeastern Massachusetts along the northeastern edge of the Avalon terrane have at one time or another been collectively called the Salem Gabbro-Diorite by many workers (e.g., Bell and Alvord, 1976;

after Emerson, 1917 and LaForge, 1932) due to similarity in appearance and structure setting to gabbros and diorites that crop out in the vicinity of Salem, MA (Toulmin, 1964; Dennen, 2007). Much of these rocks have not been distinguished from one another due to the urbanization of the area and superposed glacial deposits. Many of these rocks have been assigned an age of Proterozoic Z because they are reportedly intruded by Proterozoic granitoids of the "Dedham" suite (Zen, 1983; Wones and Goldsmith, 1991). Dioritic and gabbroic rocks of similar structural setting and appearance, however, have been observed intruding "Dedham"-age granitoids west of Boston (Kopera, 2006; Wones and Goldsmith, 1991). Thompson (2008b) also obtained a U/Pb age of 392 +/- 4 Ma for the Salem gabbro-diorite. Thompson et al. (2010) obtained a U/Pb age of 488.53 ± 0.81 Ma for gabbro locally associated with a 488.48 ± 0.79 Ma syenite at Nahant that cut a syenodiorite sill there. Thus, an age of Proterozoic through Devonian is given for ZDd in the vicinity of SAIR. *GRI Source Map ID 75579* (Preliminary SAIR Report)

ZDgdta - Aplitic granodiorite (Proterozoic to Devonian)

(description modified from Kaye, 1980)

Granodiorite-aplite. Very fine-grained and light-pinkish-gray in color. This rock has the same mineralogy and texture as tonalite-granodiorite (ZDgdt) but is much finer grained. *GRI Source Map ID 75579* (Preliminary SAIR Report)

ZDgdt - Tonalite to granodiorite (Proterozoic to Devonian)

Includes unit: **ZDgdtfb** - Tonalite to granodiorite, fault breccia (Proterozoic to Devonian)

(description modified from Kaye, 1980)

Texture is uniformly fine-grained and light- to dark-gray in color. Megascopically, femics are in characteristically uniform shapes. Microscopically, idiomorphic oligoclase occurs in stubby zoned crystals, comprising 25-55% of the rock; Xenomorphic orthoclase or microcline, 0-15%; quartz in equigranular clusters, 30-60%; and hornblende and biotite about 15%. Feldspars are largely to entirely altered to saussurite and fine sericite; quartz, badly strained. Femics are largely to entirely altered to chlorite and epidote. Southern part of outcrop in Spot Pond area shows partial assimilation of older rocks.

AGE AND REGIONAL CORRELATIONS: ZDgdta and Zgdt were formerly mapped as the Newburyport Quartz Diorite by Emerson (1917) and LaForge (1932), an outdated and erronous correlation (Wones and Goldsmith, 1991, page 1-52). Correlations with rocks of similar composition in the area are problematic for the reasons discussed above under ZDd. *GRI Source Map ID 75579* (Preliminary SAIR Report)

Boston Bay Group (NeoProterozoic to Lower Cambrian)

(description modified from Kaye, 1980)

The Boston Bay Group is not well exposed in the study area. The lowest member, the Roxbury Conglomerate consists of pebble- to cobble-sized conglomerate with rare boulders. Clasts, rounded to subrounded, are a mixture of volcanic rocks, quartzite, and granite in varying proportions. The matrix is arkosic sandstone which becomes argillaceous near the contact with overlying Cambridge argillite. Bedding is thick to massive. Pebbles tend to lie flat in the plane of bedding and therefore indicate

attitude even in massive beds. Also present within the conglomerate are beds of argillacious sandstone and siltstone similar to Cambridge argillite and diamictite consisting of poorly sorted conglomerate. Clasts in the diamictite range from small pebbles to boulders in a sandy-silty matrix. The Roxbury Conglomerate is reported to both conformably (LaForge, 1932; Billings, 1929; Goldsmith 1991A, page E28) and unconformably (Goldsmith, 1991A, page E23) overly the Mattapan and Lynn volcanics (Zlv; see discussion below).

The Roxbury Conglomerate grades upward into the Cambridge Argillite. The argillite is dominantly gray, buff, to locally purple, laminated to massively bedded, argillacious sandstone and interbedded quartzites and siltstones. Bedding plane partings are generally poorly developed with a locally imperfect slaty cleavage.

AGE: *(text modified from Thompson et al., 2007)* Deposition of the lowermost Squantum member of the Roxbury conglomerate, as designated by the stratigraphic models of Emerson (1917), LaForge (1932), and Billings (1976), has since been considered to have occurred at younger than ca. 593 Ma (Thompson and Bowring, 2000; Thompson et al., 2007). Correlation of the Squantum member with rocks described as Roxbury Conglomerate in the vicinity of SAIR and elsewhere in the Boston Basin, however, are considered tenuous at best (D. Bailey and M. Thompson, personal communication, 2010). In the vicinity northern half of the Boston Basin, the Cambridge Argillite contains acritarch microfossils ((Lenk et al.,1982) described as most common in deposits of Vendian age (Vidal, 1976; 650-543 Ma; Ediacaran Period in Late Proterozoic of Knoll et al., 2004). A volcanic ash bed estimated (owing to intervening faults) to lie ~500 m below the fossil locality has yielded a range of zircon dates; the youngest of which is a concordant analysis at 570 Ma (Thompson and Bowring, 2000). *GRI Source Map ID 75579* (Preliminary SAIR Report)

The Boston Bay Group is comprised of the following two units:

ZCrcca - Roxbury Conglomerate and Cambridge Argillite, undifferentiated (NeoProterozoic to Lower Cambrian)

see Boston Bay Group unit description. *GRI Source Map ID 75579* (Preliminary SAIR Report)

ZCrsca - Argillacious sandstone and siltstone and Cambridge Argillite, undifferentiated (NeoProterozoic to Lower Cambrian)

see Boston Bay Group unit description. *GRI Source Map ID 75579* (Preliminary SAIR Report)

Zvk - Quartz keratophyre and keratophyre (NeoProterozoic)

(description modified from Kaye, 1980)

These rocks occur as massive flows, triceratops breccias, pillow lavas, and laminated devitrified palagonite-tuff. They inter-tongue with rhyolite of the Lynn Volcanics (Zlv) eastward. Correlative with Brighton Melaphyre, in part, and Marlboro Formation (unit since redefined by Zen, 1983), in part as described by LaForge (1932). Included as part of Lynn Volcanic Complex by Zen (1983). *GRI Source Map ID 75579* (Preliminary SAIR Report)

Zlv - Lynn Volcanics (NeoProterozoic)

Includes unit: **Zlvfb** - Lynn Volcanics, fault breccia (NeoProterozoic)

(description modified from Kaye, 1980)

The Lynn Volcanics, as mapped, are rhyolite and rhyodacite consisting of pelsitic and porphyrofelsitic, flows, welded-ash flows, vitric, lithic, and lapilli tuffs, flow breccias, breccia pipes and extrusion domes. Textures are felsitic, porphyritic, trachytic, and pyroclastic. They are generally microporphyritic in a slightly translucent groundmass. Rocks are black, red, white, cream, and shades of reddish- and greenish-gray. The volcanics are generally massive but with fine flow-lamination in welded-ash flows. Stratification partings are locally developed in ashy tuffs and in thin-layered flows.

Bell (1977) described three distinct facies of the Lynn Volcanics. They are not distinguished from one another, however, on his map. His descriptions of each of these facies are repeated here verbatim:

Drab rhyolitic facies - Predominantly porphyritic-flow rock and welded tuff crudely interlayered with minor lenses of tuff, tuff breccia, and agglomerate. These rocks are dull shades of gray, greenish-gray, reddish-gray, or buff; minor lenses, streaks, and blotches of darker brownish- to purplish-red rock are enclosed in them. They mostly weather to grayish or whitish surfaces characterized by spalling of thin chips 1/2 to 1 1/2 cm. diameter. These rocks differ from those of the reddish rhyolitic facies by color, by having a slightly greater proportion of plagioclase phenocrysts, by having more abundant spherulites, and by having none or very little dust-like iron oxide dispersed in the groundmass. Parts of these rocks contain detritus derived from the subjacent Dedham Granodiorite [Zgdm, ZDgdt, Zgrt in this study].

Andesitic facies - Very fine-grained, dark gray or dark greenish-gray, dense, featureless rock except for scattered amygdules. It is cut by many small, irregular veins and veinlets of epidote. Thin sections show this rock to be somewhat porphyritic, tiny plagioclase phenocrysts being enclosed in a very fine-grained pilotaxitic groundmass. It is considerably altered, all feldspar being completely clouded by saussuritization; phenocrysts are partly replaced by epidote; mafic minerals have been completely altered to chlorite. It consists of about 65 percent crudely aligned plagioclase microlites, 1 percent plagioclase phenocrysts, 5 to 10 percent epidote, 5 to 10 percent chlorite, 5 percent dusty to finely granular opaque matter, and the remainder being greenish to brownish semi-opaque interstitial matter. The plagioclase is andesine or labradorite; its altered condition precludes a more exact identification. The amygdules consist of extremely fine-grained, ami-opaque gray substance cut by minute quartz veinlets.

Agglomeratic-tuffaceous facies - Mainly pyroclastic rocks, agglomerate, tuff breccia, and tuff, enclosing minor lenses of welded tuff and flow rock. These rocks are predominantly brownish-red, purplish-red, or pinkish and enclose minor lenses of gray, buff, or pale green to greenish-gray rock. The surfaces of the reddish parts retain their color or become darker red when weathered; the other parts weather to grayish or whitish surfaces. These rocks range from very fine-grained equigranular tuffs to coarse agglomerates having large angular fragments. The finer grained tuffs contain large proportions of cryptocrystalline shards, the remainder of the rock being a cryptocrystalline to semicryptocrystalline mixture of quartz and feldspars. Somewhat coarser-grained tuffs contain from 1 to 20 percent subhedral to anhedral feldspar crystals, generally having corroded and rounded edges, in a fine-grained tuffaceous matrix. The feldspars are incipient or poorly developed microperthite, albite, and oligoclase. The aggloaerates consist of fragments of volcanic rock, mostly rhyolitic, but including minor quantities of andesite and basalt, in a tuffaceous matrix. Welded tuff and flow rock are as described above. Parts of these rocks contain minor quantities of detritus derived from the subjacent Dedham Granodiorite [Zgdm, ZDgdt, Zgrt in this study].

REGIONAL CORRELATION: The Lynn volcanics are correlative with the Mattapan Volcanic complex on

the south side of the Boston Basin based on similar lithologies and stratigraphic and structural position (Goldsmith, 1991A) in addition to age (Thompson et al., 2007). Both have been observed to lie non-comformably on rocks described in the literature as "Dedham" granite / granodiorite (see below; LaForge, 1932, page 31) and overlies the older Middlesex Fells volcanics and diorite that intrudes it to the west (Bell, 1976, page 289). Kaye (1980) shows a portion of the Lynn volcanics in intrusive brecciated volcanic-pipe contact with Zgr.

The Lynn Volcanics in the vicinity of SAIR are in fault contact with the Boston Bay group, though the correlative Mattapan volcanics are overlain by the group south of Boston (see above). The Lynn and Mattapan volcanics are interpreted to be the extrusive equivalents of various phases of ca. 625 Ma to 590 Ma Avalonian granitoidal batholithic and volcanic rocks in eastern Massachusetts (Thompson et al., 2007; Thompson et al., 1996).

AGE: 596 Ma (U/Pb) from rhyolite exposed within Aggregate Industries quarry in Saugus (Hepburn et al., 1993). *GRI Source Map ID 75579* (Preliminary SAIR Report)

Zqo - Quartzite and Olistostromal Assemblage (Proterozoic)

(description modified from Bailey et al., 1989)

The lower portion of this assemblage, poorly exposed in the western part of the outcrop area in the vicinity of SAIR, predominantly consists of dark chlorite-grade metamorphosed siltstones, mudstones, and very fine-grained sandstones. Parts of this sequence are slump folded and several intervals, up to tens-of-meters-thick, contain irregular masses of meta-quartzarenite that are interpreted as olistostromes (Bailey et al. 1989). The eastern portion of the outcrop belt, which is the upper half to third of this sequence, consists of metaquartzarenite masses and beds interlayered with thinly laminated meta- siltstones, mudstones, and very fine sandstones with commonly occurring slump folds and olistostromes. The olistrostromes in both portions of the outcrop belt consists of massive, moderately to well-sorted, medium-grained, muscovitic quartzite. Intervals of chaotic mixtures of quartzite pods in a meta-mudstone, silstone and quartzwacke matrix are common.

Due to the extensive faulting in the area, strata cannot be correlated from one fault block to another. Bailey et al. (1989) provide detailed stratigraphic sections and outcrop maps of this assemblage in the vicinity of SAIR. Unfortunately, the maps therein were of insufficient cartographic accuracy to be incorporated into the attached GIS database and map. Attempts by the compiler to obtain more cartographically accurate maps for this map unit were unsuccessful.

AGE AND REGIONAL CORRELATION: The assemblage described above has historically been grouped with the Westboro formation (e.g. Emerson, 1917; Bell and Alvord, 1976; Zen, 1983) due to similar lithology and structural position on the western flank of the Avalon terrane. It has also been correlated with similar assemblages in the Blackstone Group of Rhode Island and Southeastern Massachusetts (Bailey et al., 1989; Goldsmith, 1991a). Correlations with the Westboro formation are problematic, however. The Westboro at its type locality is not clearly intruded by granitic rocks and has been interpreted by various workers to noncomformably overly, or be in fault-bounded contact, with ~612-606 Ma (SHRIMP U-Pb age; Walsh et al., 2009) batholithic granitoids there (e.g., Bell and Alvord, 1976; J. Kopera, field observations 2003-present). U-Pb analyses from zircons at the type locality are interpreted to yield a maximum depositional age of ~600 Ma (Hepburn et al., 2008). The assemblage present in the vicinity of SAIR is intruded by the "Dedham" granite (Kaye, 1980; Zgr, Zgdm, ZDgdt, Zgrt in this study]) that, in the general Boston area, yields an age of ~610 Ma (Hepburn et al., 1993; Ault et al., 2004). Zartman and Naylor (1984) obtained an age of ~630 Ma for "Dedham Granite" from Saugus, MA (exact location and lithology unknown). This, of course, presents the problem of stratified rocks being

intruded by granitoids that are older than them-- a geologic impossibility. Until detailed and modern geochronology is done for Zqo and the intrusives in the vicinity of SAIR, regional correlations will remain unclear. It may be that Zqo is more correlative with older, similar assemblages of the Blackstone group which crop out as large inclusions in, and are cross-cut by, the ~612-606 Ma batholithic rocks in southern Massachusetts. Although the assemblage near Saugus could be of a similar age with the Westboro sensu stricto and deposited on top of older, ~630 Ma granite and cut by younger intrusives, no clear depositional relationship between the assemblage and granitoids in the vicinity of Saugus has been reported in any of the literature reviewed. *GRI Source Map ID 75579* (Preliminary SAIR Report)

Zmu - Mafic metavolcanic xenoliths of unknown affinity (Proterozoic)

(description modified from Bell, 1977)

This rock type occurs as map-scale xenoliths in ZDgdt and Zlv. It consists of fine-grained, dark gray, dark greenish gray, or black mafic metavolcanic rocks. It is intruded by many irregular veinlets of epidote and of surrounding granite. Metamorphic foliation parallels bedding or layering; many local distortions of it are caused by epidote and granite veinlets. Except for introduced material and opaque matter, the rock is equigranular, consisting of: plagioclase, 30~50 percent; hornblende, 50-70 percent; opaque granules, 0.5-2 percent. The plagioclase is untwinned oligoclase. All of this rock contains clots and veinlets of introduced epidote and of quartz, occasionally accompanied by minor quantities of potassium feldspar and microperthite.

These rocks are of unknown affinity. Bell (1977) correlated them with similar rocks exposed in the Blackstone Group of southern Massachusetts and Rhode Island presumably based on similar lithology and intrusive relationships. It is worth noting, however, that the xenoliths only occur in ZDgdt and Zlv, and may be xenoliths of potentially undifferentiated metamorphic rocks exposed to the north in the Reading quadrangle (Castle et al., 2005). *GRI Source Map ID 75579* (Preliminary SAIR Report)

Zgrt - Trondhjemite (Proterozoic)

(description modified from Kaye, 1980)

Rock is coarse-grained, light-gray intrusive. Oligoclase comprises about 50% of the rock; orthoclase less than 10%; quartz about 40%; hornblende and biotite(?) about 5%, with trace amounts of sphene. Hypidiomorphic granular texture. Alteration: oligoclase to sericite; quartz, badly strained; hornblende to chlorite; biotite to chlorite. Much cataclasis and internal strain (bent twin lamillae in oligoclase). Intrudes surrounding volcanic rocks. *GRI Source Map ID 75579* (Preliminary SAIR Report)

Zgdm - Granodiorite to quartz monzonite (Proterozoic)

(description modified from Kaye, 1980)

Fine- to medium-grained; light gray, pink, and green in color. Oligoclase comprises about 50% of rock; orthoclase, 20-40%; quartz, 20-30%; chlorite, epidote, sericite replace biotite; sphene. Hypidiomerphic granular texture. Oligoclase is slightly to completely saussuritized. Orthoclase is lightly dusted with sericite. Biotite is completely altered and quartz is severely strained. *GRI Source Map ID 75579* (Preliminary SAIR Report)

Zgr - Granitoidal rocks, undifferentiated (Proterozoic)

(description from Kaye, 1980)

Fine- to coarse-grained, dark- to light-colored, alkali granite to gabbro. *GRI Source Map ID 75579* (Preliminary SAIR Report)

GRI Source Map Citations

The GRI digital geologic-GIS map for Saugus Iron Works National Historic Site, Massachusetts (SAIR) was compiled from the following source:

Kopera, Jospeh P., 2011, Preliminary Compilation of Bedrock Geology in the Vicinity of Saugus Iron Works National Historic Site, Preliminary SAIR Report, Massachusetts Geological Survey, 1:24,000 scale. (Preliminary SAIR Report) (*GRI Source Map ID 75579*)

Additional information pertaining to each source map is also presented in the Source Map Information (MAP) table included with the GRI geology-GIS data.

Preliminary Compilation Ancillary Data

Kopera, Jospeh P., 2011, Preliminary Compilation of Bedrock Geology in the Vicinity of Saugus Iron Works National Historic Site, Preliminary SAIR Report, Massachusetts Geological Survey, 1:24,000 scale. (GRI Source Map 75579)

Preliminary Report

Report on the Bedrock Geology in the Vicinity of the Saugus Iron Works National Historic Site (SAIR)

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INTRODUCTION

This report accompanies a digital GIS database comprising a map of the bedrock geology within an approximate 2-mile radius of SAIR at 1:24000 scale. The map largely consists of previous 1:24000 scale mapping conducted in the area by the USGS Geological Survey (Bell, 1977; Kaye, 1980) which has been edited and updated for continuity of bedrock features between the maps and conformity with unit names, ages, and interpretations that have arisen in the 30+ years since the above maps were published.

SUMMARY OF WORK CONDUCTED FOR THIS PROJECT

Literature review and field reconnaissance were conducted by Joe Kopera from 2009 to 2011. After initial field reconnaissance, it became clear that 1.) The bedrock geology that can be portrayed at 1:24,000 scale is already well documented on existing maps and 2.) construction of a more detailed / improved map of the area is possible (e.g., splitting out volcanic subunits and documenting smaller-scale structural features), but would entail a mapping effort well beyond the timeframe and geographic extent of the proposed project. This is largely due to the complexity of the local and regional bedrock geology and the urban setting of SAIR. Effort was instead focused on integrating pre-existing maps with contemporary literature and models of the regional geology.

A data layer depicting locations of bedrock outcrops and areas of shallow bedrock was not included in this report. This information for the Boston area is currently being field checked and revised by the USGS as part of the production of USGS Open File Report 2006-1260-D, scheduled to be released in 2012. Digitization of such data from older sources (Bell, 1977; Kaye, 1980) for this study would be a duplication of effort and would be rapidly superseded by the USGS's work. For more information regarding OFR 2006-1260-D, contact Byron Stone (USGS) at bdstone@usgs.gov

GEOLOGIC SETTING

SAIR is located at southern end of rocky uplands that form the northern border of the topographic and geological feature in eastern Massachusetts known as the Boston Basin (figure 1). In the context of regional geology it is located in a belt of late Proterozoic (Z) volcanic, meta-sedimentary and batholithic rocks that are typical of the northern portion of the Avalon terrane in Massachusetts (figure 1; Goldsmith, 1991A; Zen, 1983). The Avalon terrane is a group of Proterozoic through Cambrian rocks extending along the length of the northern Appalachians (Hibbard et al., 2006). The terrane formed in the middle latitudes along the margin of Gondwana during the NeoProterozoic (Thompson et al., 2007; and references therein). It was accreted to the margin of Laurentia (proto-North America) in the Paleozoic during the Acadian and/or Alleghenian orogenies; a topic that is still under lively debate.

In southeastern New England the Avalon terrane is mostly represented by Proterozoic-age batholithic granitoids. These rocks have been historically grouped in eastern Massachusetts as the Dedham Granite near Boston and the Milford Granite to the west and southwest of Boston. Such granitoids intrude older meta-sedimentary and metavolcanic packages of rock (e.g., the Westboro and Blackstone formations). The granitoids are generally overlain by Late Proterozoic volcanic sequences (e.g., the Mattapan and Lynn volcanics, the Middlesex Fells volcanics) and late-Proterozoic to early Cambrian sediments (Goldsmith, 1991A). Locally, the volcanic sequences are intruded by rocks related to the granitoids they overlie. In the immediate Boston area, the volcanics are overlain by a small basin containing the turbiditic sediments of the Boston Bay Group (Goldsmith et al., 1991A; Bailey and Bland, 2001). The batholithic granitoids are overlain to the south of Boston by the Carboniferous sediments of the Narragansett Basin. Locally, the Avalon terrane is intruded by a series of Paleozoic granitoids (e.g., Peabody Granite, Cape Anne Pluton, Quincy Granite; Goldsmith, 1991B; Wones and Goldsmith, 1991; M. Thompson, 2011, personal communication) to dioritic intrusives (see below).

The bedrock in the immediate vicinity of SAIR consists of fault bounded blocks of Proterozoic meta-quartzites, olistostromes and volcanics nonconformably overlying and intruded by a suite of batholithic granitoidal rocks (figure 2). These small fault blocks are bounded to the north by the larger Walden Pond fault which separates these rocks from Proterozoic through Devonian intrusives and presumed

volcanics (Goldsmith, 1991a; Wones and Goldsmith, 1991) represented in this study area by the Peabody Granite (Dpgr) and Quartz Diorite and Diorite (ZDd). To the south the Northern Boundary Fault separates the volcanic sequence from the nonconformably overlying sediments of the Boston Bay Group.

The volcanic and granitoidal rock sequence bounded by the Walden Pond and Northern Boundary Faults consists of, from oldest to youngest, Proterozoic quartzites and olistostromes (Zqo; called Westboro quartzite after Emerson, 1914; LaForge, 1932; Kaye, 1980; and Bailey, et al., 1989) intruded by granite (Zgr). These are nonconformably overlain by the Lynn volcanics (Zlv) and keratophyric volcanic rocks (Zvk), respectively. Zvk and the Lynn Volcanics locally interfinger with one another and are generally interpreted as partially coeval although portions of Zvk overly the Lynn Volcanics as interpreted by Kaye (1980). All of the above rocks are intruded by a suite of granitoids, granodiorites, tonalites, and trondhjemites; sequentially, by Zgdm, Zgrt, ZDgdt and ZDgdta. Kaye (1980), though, describes Zvk as lying nonconformably on Zgdm and not intruded by it.

Figure 2 shows the relative age relationships among the above units. This figure was prepared in lieu of several cross sections of the geology underlying SAIR. The compiler feels that given the relatively small map area, the density of faulting therein, and the near chaotic orientations of rare structural measurements of stratified rocks do not allow for a cross section(s) that would usefully illustrate the relationships between the map units in immediate vicinity of SAIR.

STRUCTURAL GEOLOGY

The dominant structural features in the vicinity of SAIR are a series of east-west trending, north-dipping reverse and thrust faults. These faults commonly have brecciated zones of country rock bordering them (Bell, 1977; see map). Kaye (1980) maps these faults as cutting more north-sound oriented strike-slip faults and inferred faults of uncertain motion, dividing up the bedrock into several discrete fault-bounded blocks. The density of such faults and the urban setting make it a difficult task to correlate strata between blocks to determine if there are any map-scale ductile structures, such as megascopic folds, in the volcanic and metasedimentary rocks. The age of the reverse faults is at least post-Devonian as the Walden Pond fault cuts the Peabody granite (Dpgr). If the faults are close to Devonian in age they have most likely been reactivated later during the Pennsylvanian, Permian, or Mesozoic (Goldsmith, 1991B and references therein; Kopera, field observation, 2003-present). This places the reverse faults at having their origin in either Acadian tectonism during the Devonian or Alleghenian tectonism during the Carboniferous and Permian. Faults of similar orientation also cut the Boston Basin immediately to the southeast, and have similar strike to the axial planes of large folds within the Boston Basin and Carboniferous-Permian Narragansett Basin in southeastern Massachusetts. This implies that the reverse faults were probably active during the Permian, or later, given the regional stress orientations to produce folding of similar orientation in the Narragansett Basin. However, it does not rule out an older age for the reverse faults.

The north-south oriented faults in the vicinity of SAIR are mapped by Kaye (1980) as being cross-cut by the reverse faults discussed above. The two fault sets could have formed penecontemporaneously with the EW-trending faults having reactivated during later tectonism. Throughout eastern Massachusetts, however, several Mesozoic-age faults with north-south orientations cut east-west trending features, including reverse faults, especially along the southern margins of the Boston Basin and both margins of the Narrangansett Basin. It could be that the NW faults are later in age than the EW-trending reverse faults and cross-cutting relationships were misinterpreted by Kaye (1980). Unfortunately, the actual traces of these faults and their intersections in the vicinity of SAIR lie under thick glacial cover, making an exact determination of their relative age in the study area conjectural.

Bailey et al. (1989) infer the presence of map-scale folds in fault-isolated blocks of Zqo based on the orientations of bedding therein. Kaye (1980) shows bedding in this unit to be locally contorted, although this may be slump folding as discussed in Bailey et al. (1989). The age of this folding could be late

Proterozoic through Permian (Alleghenian). Folding or ductile deformation in the Zlv and Zvk volcanic assemblages near SAIR is as of yet undocumented and may be due to the complicated sedimentary-volcanic nature of sequence, lack of good exposure due to the urban setting, or the massive nature of the rhylotic flows therein, making orientation measurements of layering / bedding with high certainty difficult.

METAMORPHISM

Zqo has been metamorphosed to chlorite grade (Bailey et al., 1989) with higher temperature mineral assemblages present closer to intrusive contacts. Bell (1977) discusses chlorite alteration of mafic minerals in the andesitic facies of Zlv, in addition to epidote alteration and sausserization of feldspars. Rocks in Avalon terrane in the immediate vicinity of Boston have generally not achieved greater than chlorite grade metamorphism (Goldsmith 1991b) which, in immediate Boston area, is likely to be associated with Alleghenian tectonism.

BEDROCK ECONOMIC GEOLOGY

Several abandoned crushed stone quarrying operations exist west of the Newbury Turnpike in the western edge of the study area (USGS Mineral Resources Data System - http://tin.er.usgs.gov/mrds/ ; accessed 8/2011; see accompanying GIS database for quarry locations and names) and are now occupied by commercial buildings. The only active quarry is the Saugus quarry operated by Aggregate Industries Northeast, Inc. Several ponds in the area that are underlain by ledge / outcrop have straight edges and / or orthogonal corners of different orientation than topographic lineaments, suggesting that they may be flooded quarries. A survey of the town historical records in the area have not clarified whether these ponds in fact are abandoned quarries. The quarries are either in Zlv or intrusive rocks.

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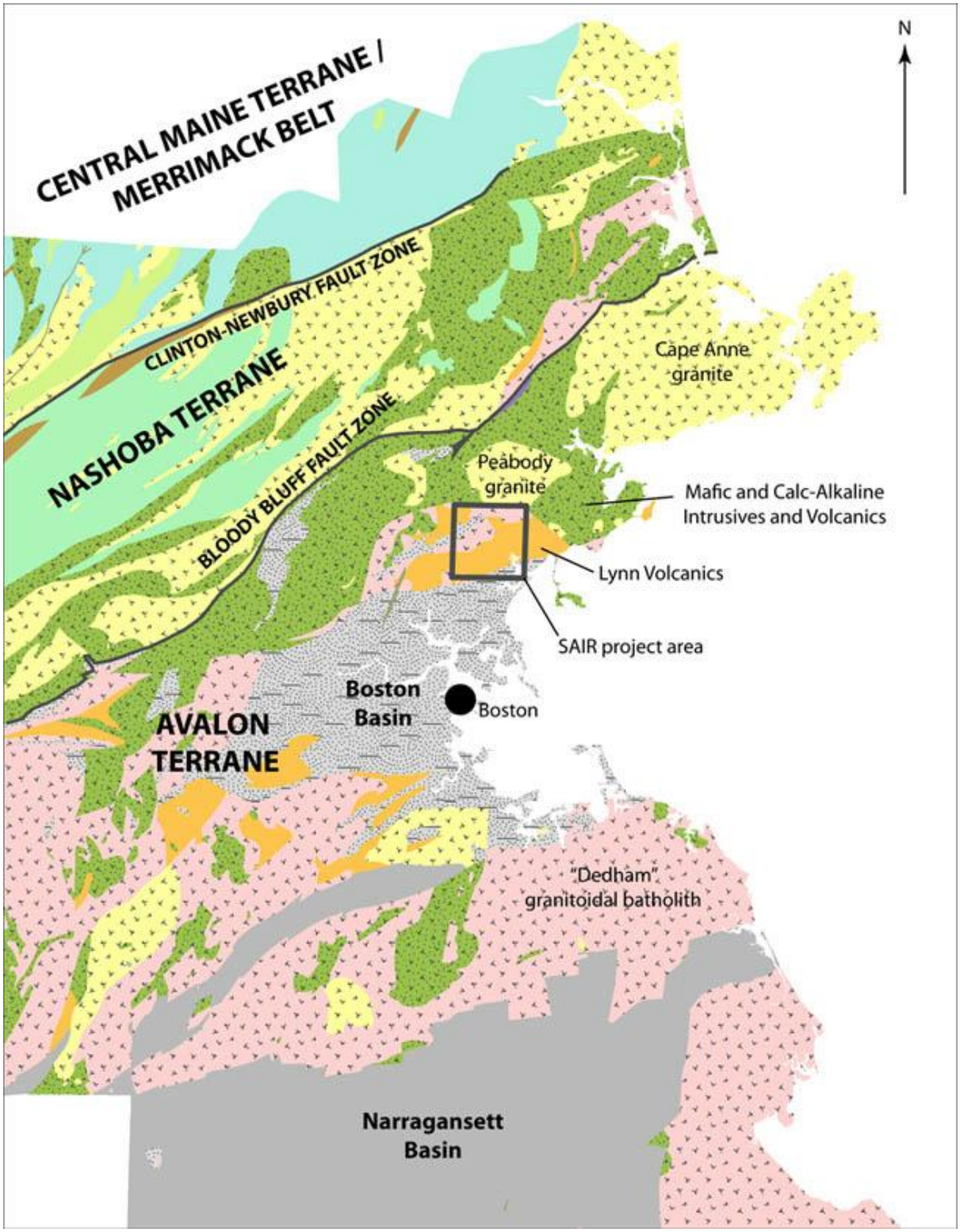
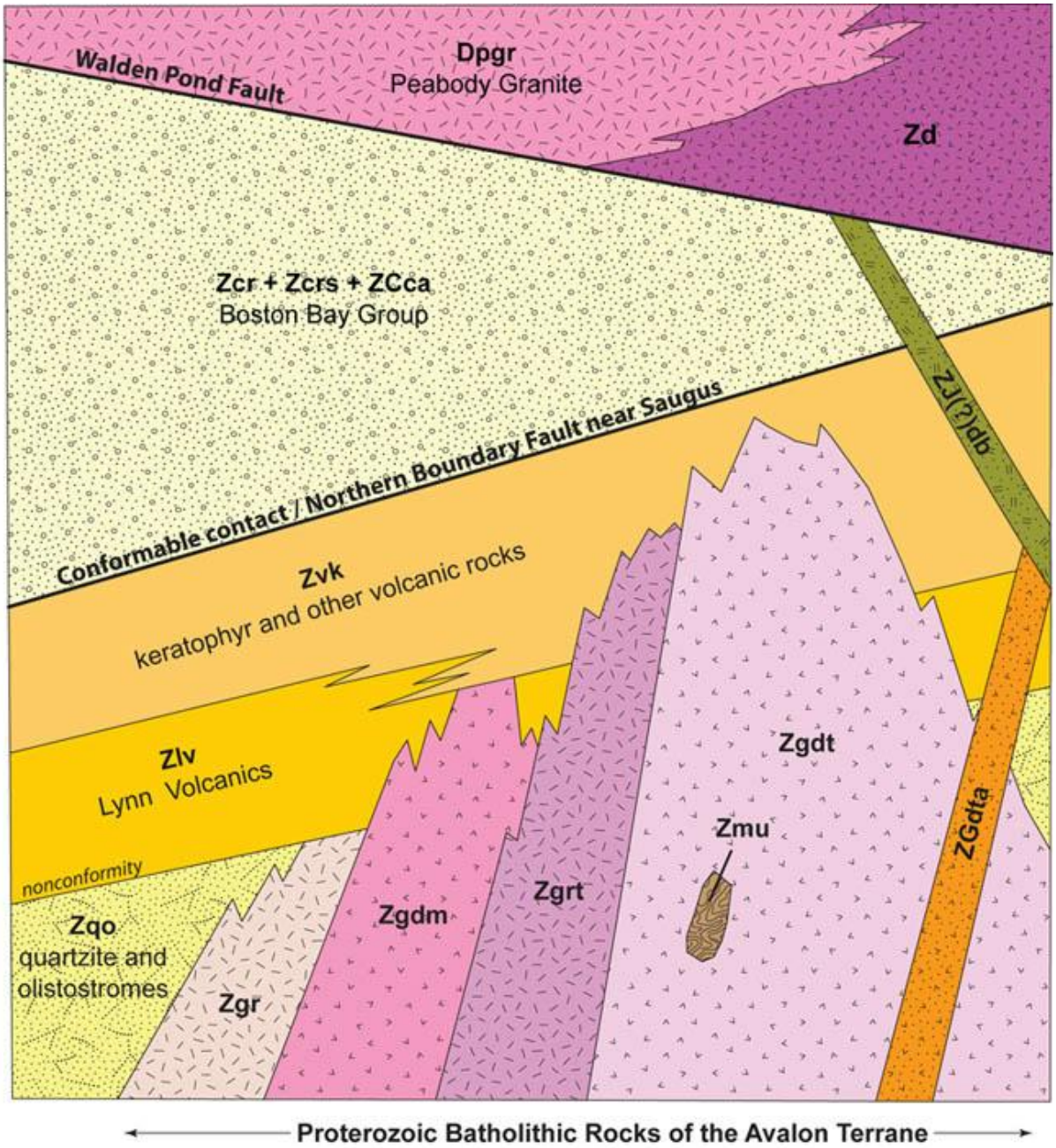
Extracted from: (Preliminary SAIR Report)

Preliminary Report Figure 1



Extracted from: (Preliminary SAIR Report)

Preliminary Report Figure 2



Extracted from: (Preliminary SAIR Report)

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