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NEW YORK STATE MUSEUM
CHARLES C. ADAMS, Director

GEOLOGY OF THE SANTA CLARA QUADRANGLE, NEW YORK

By A. F. Buddington
Temporary Geologist, New York State Museum

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Erratum
The illustrations on page 13 and page 25 should be interchanged. The illustration on page 25 is figure 2, and the illustration on page 13 is figure 5.
INTRODUCTION
LOCATION AND CULTURE
The Santa Clara quadrangle is located in Franklin county, New York, near the northern border of the Adirondack mountains (figure 1). Although two through highways traverse the area, the country is so rugged on a moderate scale (figure 2) and the valley soils are of such a character that the country is largely forested and sparsely settled. There is a small village and post office at Santa Clara, which is served by the railroad. Summer resorts are located at McCollums,
Meacham lake and Lake Titus, and there are a number of private estates on other lakes and rivers. Lumbering is the principal industry. Facilities are provided at a number of places for hunters and fishermen, and a little dairying for local consumption is carried on along the main highways.

ST LAWRENCE LOWLANDS AND ADIRONDACK HIGHLANDS

The junction of the St Lawrence Lowlands physiographic province and the Adirondack Highlands province lies in the Malone quadrangle, but a few miles north of the border of the Santa Clara quadrangle. There is a very marked contrast between the St Lawrence lowlands, with their cleared fields and many prosperous dairy farms, and the forested and sparsely settled Adirondacks. The change of culture is almost as sharp as the change in bedrock geology and nearly coincident with it.

RELIEF

The lowest altitudes in the Santa Clara quadrangle are at the north where the Deer river, Little Salmon river and Lake Titus streams leave the quadrangle at elevations of about 1150, 1250 and 1375 feet respectively. At the south border of the quadrangle, the St Regis river enters the area at an altitude of about 1540 feet, and the Osborn river at about 1550 feet. The highest peak in the region is Rice mountain at 2525 feet. The differential relief is in general moderate, and for the higher hills ranges between 700 and 1000 feet.

SUMMARY OF BEDROCK GEOLOGY

INTRODUCTION

The area of the Santa Clara quadrangle is unusual in that, so far as known, all the bedrock is of igneous origin. The rocks of this area consist exclusively of igneous types which have originated through crystallization of magma which was essentially a molten solution of the minerals of which the rock now consists, plus a small amount of water and other volatile compounds or hyperfusibles which escaped during solidification. There are several kinds of igneous rock in the quadrangle, of several different relative ages, but all were formed in Precambrian time, the oldest era of the earth’s history. No exposures of the Grenville metamorphic sedimentary series, which normally forms the oldest rocks in the Adirondack area, have been found in this region, although they occur in the adjoining quadrangles
to the south, east and west. The Grenville series consists of sedimentary beds such as shale, sandstone and limestone, which have been metamorphosed to crystalline schists, quartzites, marbles, granulites and gneisses. In general they constitute the original framework into which the early magmas were intruded.

A table showing the kinds and relative ages of the rocks of the quadrangle is here given.

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<td>Pleistocene ...........................................</td>
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<tr>
<td>Stream gravels, stratified sand, flood plain alluvium etc.</td>
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<td>Till, moraine, delta sand plains, kames etc.</td>
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<td>Diabase dikes ........................................</td>
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<td>Hornblende quartz syenite with local hornblende and biotite granite facies, coarse lenticular texture</td>
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<td>Pyroxene quartz syenite, coarse lenticular texture</td>
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<td>Pyroxene quartz syenite, medium-grained contact facies</td>
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The magmas which consolidated to form the igneous rocks of this district are thought to have been derived originally from local sources many miles deep within the earth's crust, and to have worked their way up toward the surface and intruded the formations or rock complex which existed there at the time of their arrival. As shown by the preceding table, there were several epochs of magmatic intrusion, and the magmas of each epoch were more or less different in composition from each other and hence gave rise to different rocks.

**METAGABBRO**

The metagabbro is the oldest of the igneous rocks in this area. It is a relatively heavy dark-colored rock and occurs both in large areas, as north and west of Lake Titus, and as narrow bands and layers within the granite and syenitic rocks. The gabbro consolidated from a magma which, on the basis of data found elsewhere in the north-west Adirondacks, is thought to have been forced in as sills or sheets along the bedding planes of the Grenville sedimentary series. Younger intrusions have obscured evidences of a similar mode of formation for the gabbro of this region, but there is also nothing to suggest that it did not have a similar history. The gabbro is locally much injected by pink granite pegmatite veins. The gabbro has been metamor-
phosed since its crystallization to form somewhat altered facies, here called metagabbro or amphibolite.

**SYENITE-GRANITE SERIES (SANTA CLARA COMPLEX)**

At a period some time after the consolidation of the gabbro there was a renewed epoch of intrusion, and a magma of syenitic or quartz syenitic composition was forced in along the bedding planes of the Grenville sedimentary series and also into the older gabbro sills, in such a fashion that thin layers of gabbro were torn off and included within the border zones of the syenite sheets, although their central cores remained clear. That portion of the magma near the walls of the intruded mass was chilled relatively quickly and consolidated as an equigranular medium-grained greenish pyroxene quartz syenite, such as is found throughout the belt from Santa Clara northeast toward Titusville and Studley hill. The central part of the sheet of magma, however, cooled more slowly and during the long interval of crystallization underwent a differentiation in such a fashion that one part became higher in silica and alkalies and consolidated to form the hornblende quartz syenite and locally associated granite, such as forms a ring in the central southern part of the quadrangle around the Jennings Mountain mass and from Gile to Blue mountain, and the other part became less siliceous and higher in lime, iron and magnesia. The latter facies is the pyroxene quartz syenite which forms the area in the vicinity of Jennings and Rice mountains.

The three facies which have thus formed during a single epoch of intrusion and by consolidation or differentiation from the same magma will be included in this report as members of the Santa Clara complex.

**ST REGIS GRANITE**

The youngest major intrusive rock in the area is a pink hornblende granite, such as is found in the northwestern part of the quadrangle, south of Orebed mountain and elsewhere. It nearly everywhere contains narrow bands or small shreds of black amphibolite, which are interpreted as layers torn off from the older gabbro sheet and somewhat altered.

**GNEISSIC AND LINEAR STRUCTURE**

All of the igneous rocks so far described possess a more or less well-developed foliation or gneissic structure, due in part to the dimensional orientation of certain of the mineral grains or grain aggregates parallel to planes. With this may also go a relative concentration of one or more minerals in parallel layers or elongate lenses. Locally
the minerals and lenses or streaks are oriented parallel to a line which may or may not be associated with and in a plane of foliation. In either case it is called linear structure. If foliation is present the linear structure is always in its plane.

**DIABASE DIKES**

The youngest igneous rocks in the district are diabase dikes, which are usually not more than a few feet wide. They are nowhere abundant but are numerous in the northern third of the quadrangle and die out in number toward the south. They are most common in the northern sixth of the area and in the southern part of the Malone quadrangle.

**MECHANICS OF INTRUSION AND DIFFERENTIATION OF SANTA CLARA COMPLEX**

The structural history of the region can only be interpreted in the light of the structural history of the Adirondacks as a whole, and there is no agreement among geologists who have worked in this broad area as to what the details of this history are. The syenitic magma or magmas are commonly interpreted as having been intruded as a batholithic mass into the already folded Grenville series with the associated gabbro sheets. The writer here proposes an alternative hypothesis that the Grenville series and associated gabbro sheets were not at the most more than moderately folded, as a result of the intrusion of the gabbro sills and the great anorthosite massif which lies to the south, before the intrusion of the syenitic magmas, and that these were therefore of sill-like or phacolithic character. The variation in composition of the Santa Clara syenite-granite complex is interpreted as due in part to intrusions of magma of varying composition, but in very considerable part to differentiation in place with some movement of the last residual liquid granitic portion, so that gravity stratification is an outstanding feature of the complex.

**PERIOD OF OROGENIC DEFORMATION AND EMPLACEMENT OF ST REGIS GRANITE**

Subsequent to the emplacement and differentiation of the Santa Clara complex, strong deformative forces of orogenic or mountain-making intensity acted across this region and folded the entire assemblage of rocks. At a late stage in this epoch of deformation a great mass of granitic magma was intruded which, on consolidation, formed the St Regis granite. This magma on a large scale transgressed
across the folded structures of the older rocks and exhibits the relationships of a batholith. On a smaller scale it more or less followed the folded structures in phacolithic fashion. During this deformation all the rocks were strongly crushed and recrystallized, even including the granite itself. The rocks show a structure which by some geologists is interpreted as being the result of deformation and crushing before complete consolidation of the magma (protoclastic), but which on the hypothesis here proposed might equally well have been wholly accomplished in the solid state (crystalloblastic) after complete consolidation of all the magmas with the exception of much of the granite pegmatite, which shows no evidence of crushing. The gneissic structure in large part, the garnet reaction rims around the pyroxenes, hornblende and magnetite, and an unmixing of much of the microperthite (intergrowth of microcline and oligoclase) into discrete grains of microcline and oligoclase, are thought to have resulted at this time. All of this must have occurred at a depth of several miles. The hypothesis proposed by the writer is tentative only, and must be tested over a wider area.

JOINTS

The predominant joint systems or fractures in the rocks are of regional character and probably formed during the very late stages of the period of orogenic deformation.

TIME AND MECHANICS OF INTRUSION OF DIABASE DIKES

At a very much later stage, when the level of the earth now exposed had been brought much closer to the surface as a result of erosion of much overlying rock, the diabase dikes were intruded. This interpretation is based on their occurrence in clear-cut fractures in the older rocks and the extent to which they have a dense or fine-grained texture as a result of quick chilling in country rock colder because nearer the surface.

PRE-POTSDAM PENEPLAIN

West and southwest of the Santa Clara quadrangle, the surface of the Precambrian rocks passes gently beneath a cover of gently dipping sandy beds known as the Potsdam series. Locally the Precambrian surface near the border of the main outcrop of these beds can be proved to have only relatively recently been stripped of this protecting sheet, as indicated by a few scattered residual patches of sandstone still remaining miles from their main area (Reed, 1935; Cushing, 1925). The Precambrian surface where thus exposed is very flat and even—a peneplain—the result of long erosion of the old Precam-
brian topography until it was worn down to a low-lying relatively flat land, upon which the Potsdam sediments were deposited. A low, gently rolling divide or ridge of the old pre-Potsdam surface is exposed on the Malone quadrangle from Skerry to North Bangor, and the surface of the Precambrian as a narrow strip to the south of the present border of the Paleozoic beds (Malone quadrangle and extreme northwest corner of Santa Clara quadrangle) is but gently rolling where the former overlying Paleozoics have only recently been stripped off. This peneplain is warped up to the south and southeast, and has suffered much dissection by subsequent erosion.

PALEOZOIC HISTORY

There are no Paleozoic deposits in the Santa Clara quadrangle, although they occupy the St Lawrence lowlands to the north. The history of the Adirondacks in general during this time has been so excellently summarized by Newland (1932) that his description is quoted here:

The progress of base-leveling of the pre-Cambrian land was slowed up toward the last by a regional subsidence, which brought the surface near sea level. The downwarping was gradual and except for occasional oscillatory movements between one part of the region and another continued over a long period until almost all the pre-Cambrian was submerged. This submergence was the last event in pre-Cambrian time. The sediments that were laid down in the invading seas start the Paleozoic record.

Submergence of the pre-Cambrian surface in the early stages did not extend far into New York State. During the Cambrian period the Adirondacks were above sea level and still undergoing erosion. The marine invasion came from the east, and the shoreline advanced westward with the downwarping in that direction. The first notable transgression into the Adirondack region occurred in Potsdam time. Then began the deposition of quartz conglomerate and sandstone in the shallow marginal seas, starting on the east side of the region and moving around the north and south borders until in the last stage all but the western margin and the central area were covered. At the end of Potsdam sedimentation there was a change in conditions, shown by alternations of sandstones with layers containing more or less dolomite which pass into solid dolomite with small amounts of quartz. The dolomite marks the Little Falls stage, which is represented over about the same area as the Potsdam, except on the north side of the Adirondacks where a warping uplift brought the surface above the sea. The Beekmantown, also a dolomite, represents a rather local downwarping in the Champlain sector.

With the Ordovician period the marine invasion extended its limits so that at one time or another deposits were laid down over most of the State. Only the highest Adirondacks and perhaps the south-
eastern Highlands stood out during the Trenton epoch, when the waters had their maximum spread. In the later stages oscillations due to crustal warping confined sedimentation to distinct regions and to the deposition of detrital materials for the most part (Utica, Frankfort, Pulaski, and Oswego beds). At the end there was a complete withdrawal of the seas with an uplift that raised the eastern area (including the Adirondacks) permanently into land. The Adirondacks were not involved in folding but were doubtless rejuvenated to some extent by uplift. The faults that outline their eastern and southern margins were possibly initiated at this time (Taconic disturbance), although the evidence as to their age is not conclusive. The Paleozoic sedimentation (in general) came to an end with the Appalachian revolution. The older uplands (Adirondacks etc.) had their relief renewed by broad uplift and, inferentially, experienced some displacement along their borders along the fractures that had been earlier established.

**MESOZOIC HISTORY**

The Adirondacks continued to undergo erosion during the early Mesozoic (Jurassic and Lower Cretaceous) so that a peneplain may have been formed throughout them, although Newland (1932, p. 20) notes that “the remarkable peneplain of the Western Adirondack region belongs to the pre-Cambrian erosion period, preserved by the mantle of Paleozoic sediments that covered the area until the last remnants were removed in the Pleistocene ice invasion,” and evidence that this pre-Potsdam peneplain also occurs to a greater or less extent at least along the western part of the north border has been cited. A Cretaceous peneplain has been, however, commonly accepted as an explanation for the general uniformity of the higher hills in the Northern Adirondacks (Cushing, 1905).

**CENOZOIC HISTORY**

During the latter part and at the end of the Mesozoic era there again occurred a broad uplift of the Adirondack dome. During Cenozoic time the Adirondacks continued to undergo erosion and the upwarped mass, with its more or less peneplained surface, was extensively dissected with the development of the major features of the present topography. As Newland (1932, p. 22) says “Tertiary erosion accomplished no more than a partial base-leveling of the land. In the pre-Cambrian areas the Grenville beds alone seem to reveal its influence. The base-leveling was interrupted by rising of the land and the beginning of the Quaternary ice invasion.”
Figure 2  Typical topography of Santa Clara quadrangle. Looking west from Jennings mountain.
PHYSIOGRAPHY

INTRODUCTION

The present topography of the Santa Clara quadrangle in general slopes toward the northwest. This is indicated by a decline, both in the altitude of the hilltops and of the valleys. The hilltops slope about seven feet to a mile northwest, until they come within two or three miles of the present edge of the Paleozoic beds which outcrop just to the north of the Santa Clara area on the Moira and Malone quadrangles, where a more abrupt downward slope occurs. The major hilltops thus suggest relics of a former general level, gently sloping to the northwest until near the present border of the Potsdam sandstone beds, where it either bends down and passes beneath them or intersects the old, now steeper, pre-Potsdam surface at an angle. The latter hypothesis is the one in current use. The inferred former high level plain indicated by the hilltops of the Santa Clara quadrangle would then be of younger age (Cretaceous ? peneplain) than the pre-Potsdam surface represented only in the northwestern corner of the quadrangle.

From the previous description of the history of this area during the Paleozoic, Mesozoic and Cenozoic eras, the conclusion may be drawn that from the end of the Ordovician period (Taconic disturbance) to the present the Adirondacks have undergone a series of upwarpings and have been subjected to continuous erosion for this entire time of hundreds of millions of years. It is the upwarped, relatively flat surface or surfaces exposed or produced by such erosion which have been subsequently partly eroded to yield the present rugged topography, except for a small area in the northwest part of the quadrangle, where it is inferred that the Potsdam beds have been so recently stripped from the surface that it is there the pre-Potsdam peneplain which has been slightly eaten into and roughened by subsequent erosion.

INFLUENCE OF STRUCTURE OF BEDROCK ON TOPOGRAPHY

There are at least three major elements of structure in the bedrocks of this quadrangle which have had a predominating influence in controlling the shape which the hills and trends of the ranges of hills have taken under the influences of weathering and erosion. They are: (1) local degree of heterogeneity in the character of the rocks; (2) foliation; and (3) joints.
Local heterogeneous belts. All of the igneous rocks are relatively resistant to erosion, but where two rocks are interbanded, as in the case locally of granite or pyroxene quartz syenite with included bands of amphibolite, one or the other of the two rocks is the weaker, tends to erode more quickly and may weaken the mixed or banded portion of the more homogeneous rock within which it occurs. Such weak zones of mixed rock probably underlie at least some of the relatively low land southwest and southeast of Bull hill. In any case it tends to aid in orienting the trend of hills and depressions which develop.

Foliation. All of the igneous rocks of this quadrangle have a foliation or leaf structure whereby they tend to split parallel to a plane. This structure is uniformly parallel to the included bands of amphibolite. The influence of both structures in affecting the direction of trends of hills or ridges is exemplified in Conger, Ragged and Titusville mountains, where the orientation of the hills is parallel to that of the foliation. The semielliptical curve of Mutton ridge also conforms to the change in direction of the foliation of the quartz syenite around a syncline pitching southwest.

Joints. The joint control of topography is well shown in the arrangement of the hills across the southern third of the quadrangle. This belt of hills as a whole trends a little east of north. In Blue, Jennings, Little Jennings and Twin mountains the general trend of the hills is east-west to northeast, whereas the foliation of the rocks composing the hills is north-south to northwest. There are, however, two major directions of jointing throughout the rocks of this belt, one direction strikes between north-south and N. 20° W. and the other N. 70°-90° E. It is in considerable part the master jointing in an east-west to east-northeast direction which has influenced the development of the trend of this topography. The orientation of the lineal structure, the foliation, and the north to north-northwest set of joints, however, have also been important factors.

PLEISTOCENE GLACIATION

The major aspects of the topography of this area are the resultant of weathering and stream and river erosion extending over hundreds of millions of years during the latter part of which time the present valleys were all eroded, leaving the hills as residual masses.

During the Pleistocene period, however, practically the whole Adirondack mountain area was submerged beneath the ice of a continental glacier, which had spread from Labrador as a center and
reached as far south as Long Island. During the advance of the ice the bedrock of the country suffered some slight abrasion and erosion by boulders and silt frozen in the basal portion of the ice. Locally polished and striated rock surfaces formed in this manner may be found; but there is little or no evidence that the topography was in any way more than very slightly modified by erosive activities con-
nected with the glacial advance.

**Glacial striae.** Glacial striations, such as are made by boulders held in the base of the ice and dragged over the underlying bedrock, are rare in this area. Only three observations were obtained. In the northeast corner of the quadrangle striae were observed striking due south and in the northwest corner, S. 22° E.

**Glacial drift in general.** During the retreat of the ice, which took place by wasting or melting away, extensive deposits of gravel, sand, silt, clay and bouldery sands and clays, which had existed within the body of the ice, were deposited to some extent on the higher hills, but for the most part within the valleys or lowlands (figure 3). The deposits in the valleys were distributed in irregular fashion, so that in a number of cases preexisting drainage was deranged and new directions of flow were found by some streams. Lakes and swamps subsequently occupied the basins formed as a result of local damming of drainage and of irregular deposition of drift with associated depres-
sions. The term "glacial" drift is used as a general term to include all facies of the deposits formed directly from the ice or from streams and waters resulting directly from the presence or melting of the ice. The superficial aspects of the bedrock topography have been markedly modified by the deposition of this glacial drift, even though on the average it would form but a thin veneer over the bedrock. Over a third of the area of the quadrangle is so completely buried beneath the drift that no bedrock is exposed.

**Disturbed drainage.** The whole valley between Meacham lake and the Salmon river on the Loon Lake quadrangle is now deeply filled with drift. There seems little doubt that if this filling could be removed and the old bedrock exposed, a continuous valley would be found sloping toward the Salmon river. The Osgood river may, in preglacial times, have continued its course northeasterly through this valley to join the Salmon river. The East Branch of the St Regis river, the present outlet of Lake Meacham, leaves the lake over a falls in bedrock and takes a circuitous route around Conger mountain to join the main river below Santa Clara. Along a considerable
part of this course the river runs through narrow gorges, and in the two and a half miles between Everton and The Pinnacle has a drop of 125 feet. These facts indicate that it has followed this course for only a short time, for such features are quite abnormal for a river of this size in a topography of this character.

**Kame moraines and kame areas.** As the ice wasted away, the hills were uncovered first, and an irregular network of ice lay among the hills and extended as tongues up the valleys. At the front and along the borders of such ice tongues, the silt, sand, gravel and boulders carried on and within the ice were all dropped as a band of submarginal drift in most irregular fashion and in varying thickness to form kames, kame moraines, and kame areas. The great irregularity in thickness of the deposits results from original unevenness of distribution of débris within the ice, local fluctuating movements of the ice and irregularities of the ice front, and from local burial by débris of portions of the ice front with subsequent melting of the ice and irregular slumping of the overlying drift. The ice tongue often may have had a sheet of buried ice of highly irregular thickness in front of its main body, such as is known in front of many existing glaciers. The moraine-like deposits of this quadrangle all occur in the valleys and were deposited when the ice front was bordered by the water of temporary lakes. Consequently the material of which they are composed is more or less stratified in contrast to the similar moraines deposited above water. A group or belt of hills of more or less stratified drift, formed at the ragged edge of the ice, is called a "kame moraine."

If deltas are built forward into the lake from the ice, or formed so as to bury the ice edge, the kame moraine belt will merge into the delta and the delta will be said to show an "ice contact" slope on the upstream side.

A long belt of kames, bordering and merging into deltas on the east and south, extends north from Clear pond to the lower slopes of Kary mountain, and then west to take in the group of hillocks including Diamond pond. Another smaller but similar kame belt occurs at the north border of the Santa Clara delta, and another north of the Berry Pond delta. A kame belt also occurs along the Osgood river, and local kame areas elsewhere at several localities in the quadrangle.

East of Long pond, in an area about one mile wide and two miles long, is a sand plain which in general has a gently rolling surface surmounted by rounded hills, but has a much more irregular topography than that of a delta. This may be called a kame terrace, formed
Figure 3 Drift-filled lowlands, looking south-southwest from Ragged mountain.
between an ice tongue on the west and south and the hills on the north and east.

**Moraine.** The hills are mostly covered with a thin veneer of bouldery drift. Boulder moraine is particularly noticeable in the belt of hills extending for about two miles northeast of Spring cove, in the hill north of Cady brook on the road to Reynoldston, and in the hills west of Pleasant brook north of the road. In all these cases the boulders are mostly granite and have not come far. North of the range of quartz syenite hills (Mutton ridge, Sugar hill and Titusville mountain) there is a large amount of drift spread over the bedrock. There are many hills composed largely of boulders, and most of the hills are so veneered with drift that outcrops are sparse. Many of the boulders are large, ten to 15 feet in diameter.

The lowland between Twin mountain and Goodnow mountain stood for some time beneath the level of the waters in temporary glacial lakes, and is covered with a sandy soil from which projects a litter of boulders.

**Pleistocene deltas and ice-dammed lakes.** The drainage of the Santa Clara quadrangle flows in general to the northwest. During the wasting away of the Pleistocene ice cap, as has been noted, it first melted away from the hilltops and tongues of ice were left lying in the valleys, projecting far forward from the general front. Locally, there were probably island-like relics of the ice left isolated beyond the main mass, where they were protected by the shadows of hills or a veneer of rock debris residual from the dissipation of the ice. These tongues and relic islands of ice tended to block temporarily and locally the old preglaciar drainage channels with the resultant formation of temporary lakes and drainage routes quite different from those of today.

Deltas were built forward by inflowing streams or from the ice edge into the temporary lakes thus formed, their upper surface being in part above and in part just below the water level surface (figure 4). As the ice continued to melt away, successively lower outlets for the lakes were opened and their levels lowered. The deltas formed in such lakes now remain as eloquent testimonials to the existence of such former lakes. Their upper surface corresponds roughly to the lake level at the time they were built, and their steep slopes on the lake side give the order of depth of the lake at that point.

**Greater Lake Meacham deltas.** From Duane Center about three miles east to Duane stream (Loon Lake quadrangle) north of
Figure 4 Sketch to show assumed mode of origin of certain Pleisocene deltas. Valley surface slopes to left, ice front during retreat temporarily stands stationary for a time and dams the river, a lake is formed into which drainage from the ice builds a delta (D).
Walker Mill and south and southeast of Studley hill, there is a broad sand plain with the highest altitude about 1680 feet and a broad expanse between 1640 feet and 1660 feet. Another delta-like sand plain also occurs northeast of Meacham lake at the west base of Debar mountain. The west edge of these two sand plains consists of a narrow belt of kame moraine running north from Clear pond to Duane Center, and then west to Lake Duane. This feature (kame moraine) indicates the probable eastern edge of a tongue of ice lying there at that time and blocking the north-flowing drainage of this valley so as to form a lake. The lake waters were held on the north and west by ice in the valleys of the Deer, St Regis and East Branch of St Regis rivers, and on the east by an ice tongue in the valley of Duane stream and Hatch brook (Loon Lake quadrangle). The altitude of the deltas suggests that the lake in which they were built must have had an altitude of about 1660 feet. The question then arises as to how far south this lake extended. Sand plains of deltaic type also occur at or just below this level in the vicinity of McColloms, and extend south on to the north border of the St Regis quadrangle. The divide just south of Mountain lake is a little above 1660 feet. It may therefore be expected that Greater Lake Meacham either connected through this pass with a lake at similar level in the region of the St Regis lakes, such as the temporary Glacial Saranac lakes described by Alling (1919, p. 135), or else found an outlet by way of drainage to the West Branch of the St Regis river. The former seems more probable, for deltas of similar altitude occur on the St Regis and Saranac quadrangles. The McCollom delta plain is bordered on the east and west, and particularly on the south, by a knob-and-basin topography which suggests that a body of ice of quite irregular thickness lay in the valley here at the time of deposition of the deltas. The subsequent melting away of the thicker portions of the ice left basins of large or small size, such as are now occupied by Rice lake, McCollom, Baker and Mud ponds. The Duane Center delta and the one north of Meacham lake must have been built forward in part from the ice edge and morainal material along their western borders, as the altitude of the deltas is higher in this direction. At Alder creek, however, the delta slopes upward toward the east, suggesting that it was in part built forward from this direction.

Lake Santa Clara and Santa Clara delta. West of Santa Clara there is a delta sand plain occupying about three square miles (figure 5). The edge of the ice tongue which dammed the drainage of the St Regis river lay at the north side of the delta at the time of its
formation. This is known from the ice contact zone there which is indicated by the pronounced kame-and-kettle topography and by the very coarse gravels. The delta is compound, with one small portion at 1540 feet altitude, and the lower major delta at a little less than 1500 feet. The spillway for the earlier higher lake may have been by way of Stony brook (Nicholville quadrangle) to the West Branch of the St Regis river, for the divide between Stony brook and Alder brook is slightly over 1520 feet. Much of the lowland between Goodnow mountain and Twin mountain must have been under the lake at this time. The edge of the ice must also have rested in such a position as to block the drainage of the East Branch of the St Regis river as well as the drainage by way of low divides and Lake Ozonia and Dexter Lake outlets at the earliest stage; but a lower outlet than that, by way of the divide between Alder brook and Stony brook, must have been opened during most of the period of existence of Lake Santa Clara, presumably somewhere to the southwestward of the lowland at the head of Upper Goose pond and Twin brook.

Esker. A very long narrow ridge of gravel may be traced intermittently from south of Deer River flow along the east side of Dugway brook, south of Dugway brook along the east side of the road to Clear pond, and along the east side of Osgood river to the south border of the quadrangle. A similar ridge, which may be the southward extension, has been traced by Alling on the St Regis quadrangle along the west side of Black pond and through the western part of Upper St Regis lake. Thence the topography suggests a westward extension toward the Fish ponds. Such a glacial feature is known as an esker, and is thought to have been formed in a drainage channel when the ice lay over the territory, perhaps in a subglacial stream channel.

POSTGLACIAL UPWARP

It has been shown (Fairchild, 1919) from a study of the altitudes of glacial lake beaches, terraces, deltas etc. within the Adirondacks, and from uplifted marine terraces along the Hudson river, that subsequent to the disappearance of the ice sheet from this area the region was uplifted and warped. The lines of equal uplift (isobases) for this warping strike about N. 20° E. The total uplift since the ice period at Santa Clara would be about 640 feet. The amount of upward tilt in this region, at right angles to the isobases, is about three feet to a mile, with a south-southwestward slope. The upward tilting may, in slight part, have gone on during the existence of the temporary glacial lakes of this area.
Figure 5  Santa Clara delta, with Couger mountain in background, looking northeast.
Present lakes. The string of lakes and ponds along the valleys of Little Salmon river, the upper tributaries of the Deer river, Dugway brook and Osgood river are all the result of disturbance of pre-glacial drainage through irregular deposition of glacial drift, largely kame-moraines, or the formation of deltas built into large lakes temporarily formed by ice dams blocking the old directions of drainage during the period of withdrawal of the ice sheet. Rice lake, McCol- lom pond, Lake Margaret, Buck pond, Mountain ponds, Gourdshell ponds, Eagle pond, Diamond pond, Big and Little Duck ponds and Twin ponds, are all in belts of kame moraine, and occupy depressions among the hillocks and ridges of glacial drift. Clear pond, Eagle pond and Little Duane occupy depressions formed by a combination of kame deposits and sand plains. Lake Francis drains into Spring pond by seepage through the sands to the north, as indicated by the very numerous deep spring pits in Spring pond. Meacham lake occupies a part of a preglacial north-draining valley which has been clogged at the north by kame moraines and by deltaic deposits built into Greater Lake Meacham, which existed during one stage in the retreat of the ice. The sand plain stretching north-northeast from the lake is the top of the delta.

PETROGRAPHY

METAGABBRO AND AMPHIBOLITE

Dark to black rocks with the appearance of metagabbro or amphibolite occur as narrow bands across the northern part of the quadrangle, and locally as lenses, bands or schlieren, within the St Regis granite and the pyroxene-hornblende quartz syenite (border facies of the Santa Clara complex). Rocks of similar composition are known elsewhere in the Adirondacks to have had diverse origins. They may be (1) the result of recrystallization (with some losses and gains of material) of argillaceous-calcareous-siliceous beds of the Grenville series, or (2) the product of metasomatic replacement of limestone members of the Grenville series by emanations from the younger intrusive granites, and quartz syenites or (3) altered gabbro. Much of the rock under discussion in the Santa Clara quadrangle can be traced into facies showing relics of a diabasic or ophitic texture indicative of an igneous origin. There is no positive evidence that any of the rock is the product of recrystallization and replacement of members of the Grenville series, but a small part is so completely recrystallized that one can not be certain of its origin. The writer believes that the rock is almost wholly metagabbro, but it is not
impossible that a small part may have been derived from associated beds of the Grenville series.

There are two facies of the gabbro; one is more or less massive with very indistinct foliation, and with only a few narrow reticulating veinlets of granite; the other shows a marked foliation and lineal structure, locally with granitic pegmatite seams parallel to the foliation.

The metagabbro of the belt in the northeast corner is in part much injected by coarse pink granite pegmatite veins or locally shredded by granite, and in part is quite uniform amphibolite with only a sparse coarse granite pegmatite vein. Adjacent to the syenite on the southeast, the gabbro is intruded by sills of the latter.

The gabbro belt is cut off on the southwest by the granite and syenite which contain abundant inclusions of it.

In thin section the rock is found to consist of about equal parts plagioclase and ferromagnesian minerals. The mineral composition of a number of specimens, based on Rosiwal analyses, is given in the table below. The ratios of hornblende to augite to hypersthene, however, vary widely. Garnet occurs locally as more or less small euhedral grains along foliation planes, and biotite is often present as an accessory mineral, locally in some quantity.

Mineral composition of metagabbros (weight per cent)

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5491 Three-fifths of a mile northeast of Pitcher pond, Santa Clara quadrangle. Quartz and orthoclase are due to granitic impregnation.

5565 One and two-fifths miles southwest of Skerry, Malone quadrangle.

5565-b Same locality as 5505; fine-grained gneissic facies.

5499 One and two-fifths miles northeast of Pitcher pond, Santa Clara quadrangle.

4611 One-half mile east of Santa Clara, Santa Clara quadrangle.

5133 One-half mile north of Spring pond (southeast of Twin Ponds), Santa Clara quadrangle.

5525 One and one-fifth miles northwest of Pitcher pond, Santa Clara quadrangle.

5483 Railroad cut, just northwest of Mud pond, Nicholville quadrangle.

5536 One and three-fifths miles north of Pitcher pond, Santa Clara quadrangle.
The hornblende of the garnetiferous metagabbro is in massive clear grains, pleochroic from a pale yellowish brown to light brown; and in the nongarnetiferous gabbro it is pleochroic from yellow green to dark green, in part with a brownish hue. In the rocks which carry garnet there is a lower percentage of plagioclase and a difference in the character of the hornblende and lower magnetite, all suggesting that the garnet has formed at the expense of these minerals during recrystallization. The hypersthene is deeply pleochroic. Accessory minerals include magnetite, apatite, commonly biotite, occasional pyrite and rare zircons. In one specimen, minute deep green spinel grains are associated with the hornblende.

The metagabbro in general has a xenomorphic granular texture, clearly the result of deformation with concomitant recrystallization, as indicated by gradational relationships from primary diabasic or ophitic textures.

**SANTA CLARA COMPLEX**

The writer here proposes the term "Santa Clara Complex" for a group of igneous rocks which outcrop over much of the Santa Clara quadrangle, which appear to be genetically related, and the characteristic members of which are pyroxene or hornblende quartz syenite and pyroxene syenite. The complex as exposed on the Santa Clara quadrangle comprises (1) a medium-grained pyroxene-hornblende quartz syenite interpreted as a border chill facies, (2) a pyroxene quartzose syenite with a coarse lenticular structure, and (3) hornblende and biotite granite, likewise with a coarse lenticular structure. The latter two members form parts of the core of the complex. The Santa Clara Complex extends to the northeast and southwest on to areas which have not been mapped, so that its full extent is not known.

Along the northwest border the pyroxene-hornblende quartz syenite is intrusive into gabbro. The St Regis granite here appears to cut at a slight angle across the banding of the quartz syenite, and on the Nicholville quadrangle is directly adjacent to the hornblende granite of the Santa Clara Complex. Granite dikes of St Regis type have not positively been found in the Santa Clara Complex; but granite pegmatite veins thought to be related to the St Regis granite do occur occasionally in the quartz syenite.

The mineral composition of several representative specimens from each of the members of this complex, determined by the Rosiwal method, are given in the accompanying table. All percentages are in weight per cent.
### Mineral composition of members of Santa Clara Complex

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| **Biotite Granite (Coarse phacoidal structure)** | 5125          | 47.2       | 17.5    | 30.0       | 1.6    | 2.5        | 1.3     | 1.7       | 0.5     | 0.3     | 0.5   | 0.1           | 2.682  | 2.687       |
|                                                  | 4727          | 54.4       | 5.0     | 37.1       | 0.4    | 1.8        | 1.0     | 0.4       | 0.3     | 0.3     | 0.3   | 0.1           | 2.682  | 2.687       |
|                                                  | 4728          | 54.4       | 5.0     | 37.1       | 0.4    | 1.8        | 1.0     | 0.4       | 0.3     | 0.3     | 0.3   | 0.1           | 2.682  | 2.687       |
| **Hornblende Quartz Syenite (Coarse phacoidal structure)** | 5125          | 47.2       | 17.5    | 30.0       | 1.6    | 2.5        | 1.3     | 1.7       | 0.5     | 0.3     | 0.5   | 0.1           | 2.682  | 2.687       |
|                                                  | 4727          | 54.4       | 5.0     | 37.1       | 0.4    | 1.8        | 1.0     | 0.4       | 0.3     | 0.3     | 0.3   | 0.1           | 2.682  | 2.687       |
|                                                  | 4728          | 54.4       | 5.0     | 37.1       | 0.4    | 1.8        | 1.0     | 0.4       | 0.3     | 0.3     | 0.3   | 0.1           | 2.682  | 2.687       |
| **Pyroxene Quartz Syenite (Coarse phacoidal structure)** | 4725          | 47.2       | 17.5    | 30.0       | 1.6    | 2.5        | 1.3     | 1.7       | 0.5     | 0.3     | 0.5   | 0.1           | 2.682  | 2.687       |
|                                                  | 4726          | 54.4       | 5.0     | 37.1       | 0.4    | 1.8        | 1.0     | 0.4       | 0.3     | 0.3     | 0.3   | 0.1           | 2.682  | 2.687       |
| **Modified (medium-grained) Facies in Contact Zone with Metagabbro** | 4725          | 47.2       | 17.5    | 30.0       | 1.6    | 2.5        | 1.3     | 1.7       | 0.5     | 0.3     | 0.5   | 0.1           | 2.682  | 2.687       |
|                                                  | 4726          | 54.4       | 5.0     | 37.1       | 0.4    | 1.8        | 1.0     | 0.4       | 0.3     | 0.3     | 0.3   | 0.1           | 2.682  | 2.687       |

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Pyroxene-hornblende quartz syenite (medium-grained facies). A belt of medium-grained pyroxene quartz syenite extends across the central part of the Santa Clara quadrangle and, in association with local developments of mafic syenite containing included shreds and lenses of amphibolite, it also forms much of the southeast corner of the area. The rock is gneissic and on fresh surface has a pale greenish to yellowish green hue. The weathered zone immediately beneath the surface is a characteristic brown or maple sugar color. Locally there are sparse large phenocrysts of microperthite.

The mineral composition of several representative specimens is given in the accompanying table. The hornblende can in part be proved to be secondary after pyroxene, but whether all has had this origin is uncertain.

Streaked facies of pyroxene-hornblende quartz syenite. One facies of the pyroxene-hornblende quartz syenite (medium-grained) shows a marked thin banding in alternate layers, one of which somewhat resembles pegmatic seams. Most of the pyroxene-hornblende quartz syenite (1-a of map) which shows local mafic facies and contains included lenses and shreds of amphibolite shows this streaking. The lighter colored, less mafic, more feldspathic seams are usually one-fourth to one-half of an inch wide and a few to several inches in length, and a fraction of an inch to a few inches apart. These seams
are but a trifle coarser than the more mafic bands. The rock as a whole, in superficial appearance, resembles a pegmatite injection gneiss.

The streaked facies as a whole may be more quartzose and less mafic than normal; but more commonly it is less quartzose and more mafic, and thus constitutes a syenite instead of a quartz syenite. The rock of Goodnow mountain shows the less mafic type, and the belt through Cherry hill and McColloms shows the more mafic syenite. The latter is often characterized also by an abnormally large amount of magnetite and locally by apatite.

Although the development of the streaked facies appears to be related to the prevalence of amphibolite inclusions and metagabbro lenses, and is characterized by a greater percentage of pyroxene and hornblende than normal, the writer could find no relics of labradorite or andesine to suggest that the mafic character might have arisen from purely mechanical injection of metagabbro by quartz syenite magma or pegmatite. Locally the streaked gneiss is cut by distinct coarse pegmatite veins.

**Pyroxene-quartzose syenite (coarse phacoidal facies).** A pyroxene quartzose syenite with a coarse lenticular structure forms the core of the Jennings Mountain mass. It varies in color from a yellowish green to a green. The individual phacoids of granular feldspar range in general from one to two inches in length and 0.3 to one inch in width. The mafic minerals and quartz wrap around them. The pyroxene quartzose syenite can not normally in the field be certainly distinguished from some facies of the hornblende quartz syenite into which it grades. Its microstructure is also similar to that of the hornblende quartz syenite. It consists predominantly of feldspar (75 to 80 per cent) composed of about equal parts microperthite and oligoclase, 8 to 13 per cent of quartz, 3 to 5 per cent of pyroxene, a per cent or two of hornblende, 1 to 2 per cent magnetite, accessory apatite and zircon, 1 to 3 per cent secondary garnet, and locally a little secondary biotite. The microperthite commonly is microcline with only a slight to moderate amount of intergrown oligoclase. Much of the oligoclase is clear, but in part it has antiperthitic intergrowths of potash feldspar. A trifle myrmekite is present. The garnet, usually with quartz intergrowth, occurs largely as reaction rims between the mafic minerals, pyroxene, hornblende and magnetite, on the one hand, and plagioclase, on the other. Much, if not most, of the hornblende is also secondary after the pyroxene. The biotite is a pleochroic light to deep reddish brown or occasionally yellowish green variety, secondary after pyroxene. Locally,
occasional grains of titanite or pyrite are present. There are no pegmatite veins or seams in these rocks.

**Hornblende quartz syenite.** The hornblende quartz syenite might equally well be called a hornblende granite; but to emphasize its relationship to the syenitic group, and because it has only a moderate amount of quartz, the term “hornblende quartz syenite” will be used here.

Hornblende quartz syenite forms a narrow belt along the western side of the quadrangle from Blue mountain (now called Azure mountain), through Middle and West hills to a mile north of Gile, and is exposed in larger volume to the west on to the Nicholville quadrangle. It also forms the major part of a ring around the periphery of the Jennings Mountain dome, including Black, Leboeuf, Downey, Porcupine and Sugarloaf hills and the south end of Rice mountain. An isolated block included in the St Regis granite forms Cheney hill.

The rock everywhere has a marked foliation with a coarse, lenticular or phacoidal structure. The lenses are one to two inches in length and consist of equigranular aggregates resulting from crushing of original large grains. The lenses consist of microperthite or of oligoclase. The former usually weathers a pinkish color, and the latter a white or yellowish green. The fresh surface is commonly a yellowish green with the lenses of microperthite showing a tendency toward a pink or brownish tinge. Some of the more felsic facies weather so as to give the rock as a whole a distinctly pinkish hue. The mafic minerals are concentrated in thin leaves or lenses parallel to the foliation, and a few red garnets are commonly associated with them. The Cheney Hill rock consists of phacoids one to four inches in length and about one-half inch in width. The lenses consist of pink granular microperthite and white weathering oligoclase. The rock is distinctly pink on weathered surface.

There are no inclusions of amphibolite and no pegmatite seamings in any of these rocks.

The mineral composition of a number of specimens from the outer zone of the Jennings Mountain dome is given in the table showing the variations of the Santa Clara Complex.

In thin section the common type of rock in the belt through Gile and Blue mountain is seen to consist of microperthite and oligoclase with subordinate microcline, 10 to 15 per cent of quartz, 6 to 10 per cent of hornblende, and accessory magnetite, garnet, apatite and zircon. Locally, a little augite, biotite or a trifle titanite may be present.
A facies of the quartz syenite, with composition near that of the chill facies but a texture like that of the hornblende syenite and occurring with it, is exposed in the old small road metal quarry at the north end of Gile hill. It consists of microperthite 50 per cent, oligoclase 22 per cent, augite 5 per cent, quartz 19 per cent, hornblende 2 per cent, magnetite 2 per cent, and accessory apatite, titanite, and zircon. The titanite occurs as a reaction rim about magnetite.

**Biotite granite.** Bodies of biotite granite occur within the hornblende quartz syenite belt in the outer zone of the Jennings Mountain dome. It is particularly well exposed on the southwest peak of Twin mountains. At this locality it is similar in every way in color, appearance and microstructure to the hornblende quartz syenite, except that it shows quartz to be present in greater abundance. It is green on fresh surface and maple sugar color just beneath the surface. An outcrop of the biotite granite also occurs about a mile east of Benz pond. At this locality the rock is pinkish on the weathered surface with alternating brown and yellowish green lenses showing on the fresh surface.

Locally bands of similar biotite granite are found with apparently intrusive relations to the pyroxene quartz syenite of the core of the Jennings Mountain dome.

The mineral composition of several typical specimens is shown in the table. The biotite in all cases appears to be secondary after pyroxene or hornblende, as indicated by relics of these minerals. It has slightly abnormal pleochroic colors from the usual biotite of granites, showing yellowish browns and greens. One specimen (4727) shows dactylic intergrowths of quartz and biotite as a result of metamorphic recrystallization.

**ST REGIS GRANITE**

The St Regis granite is here so named from the town of St Regis Falls on the Nicholville quadrangle. A belt of pink medium-grained granite passes across the Nicholville quadrangle through this town, and its extension to the northeast underlies the northwest corner of the Santa Clara quadrangle. The granite is noteworthy for the local abundance of lenses, bands and schlieren of amphibolite, and for the especially strong development of pegmatitic facies in connection with belts of such inclusions. The pegmatite for the most part occurs as thin seams parallel to the foliation of the granite. Locally the pegmatite seams carry a little accessory magnetite. A few thin quartz veins or quartz-magnetite veins are also found. The rock, except for very local alaskitic facies has a marked gneissoid structure.
The mineralogical composition of a number of specimens is given in the accompanying table. The rock is in general a hornblende granite with microperthite the predominant feldspar. Oligoclase is always present and locally may exceed the microperthite. Microcline or orthoclase usually forms several per cent. Magnetite, apatite, and zircon are always present as accessory minerals. Titanite often occurs, in part as discrete grains, in part as a thin reaction rim around magnetite. Quartz is a major mineral. The rock locally forms an alaskitic facies (5210) in which biotite is the ferromagnesian mineral in place of hornblende.

Rarely the granite (5109) may contain several per cent of pyroxene, presumably derived from disintegration of metagabbro layers.

<table>
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4603 Nicholville quadrangle, little road metal quarry on state road, one-fifth of a mile west of outlet of Lake Ozonia.
4624 Everton road, one-half of a mile east of west border of Santa Clara quadrangle.
5240 Three-fifths of a mile southwest of junction of Cady and Pleasant brooks.
5109 Falls of Deer river at west border of quadrangle.
5210 Spur southeast from Furnace mountain.
5325 Gorge of St Regis river, four-fifths of a mile south of Blue Mountain house.
5252 West border of Santa Clara quadrangle, one and one-fifth miles south of Deer river.

**DIABASE**

Diabase dikes, which cut all the other Precambrian rocks, are numerous in the northern third of the quadrangle, but are sparse toward the south and west. They are most common in the upper sixth of the Santa Clara quadrangle and in the southern part of the Malone quadrangle. They are usually not more than a few feet wide, but occasionally are up to 25 feet in width.

The writer has made no detailed petrographic study of these dikes. They have been described in general by Cushing (1900, p. 117-22; 1905, p. 345-54), whose descriptions have been freely utilized in the following discussion. In contrast to all the other Precambrian rocks, they are entirely unmetamorphosed. They are black, very
fine-grained rocks, usually with more or less small phenocrysts of plagioclase in a groundmass which has a dense to fine ophitic texture in the central part of the dike, and intersertal or locally vitrophyric along the walls. The phenocrysts are of intratelluric origin, as indicated by their occurrence in the chilled border zones as well as in the central parts. Most of the dikes are olivine diabase composed of olivine, augite and labradorite, with a little associated magnetite. Olivine is usually present as phenocrysts or in larger grains than the augite. Possibly about one-third of the dikes are diabases without olivine. In a few dikes bronzite is present in addition to augite. In these dikes olivine retreats and the bronzite is commonly bordered by a narrow zone of augite. In about 25 per cent of the dikes biotite is present, occurring in frequent small scales in the groundmass, with a notable tendency to border the magnetite crystals.

Diabase with a little interstitial granophyre was found by the writer a mile east-southeast of Skerry on the Malone quadrangle. This consists predominantly of a few phenocrysts of plagioclase in a doleritic groundmass of labradorite and augite with a little magnetite and a trifle biotite associated with the latter. Interstitial to the general groundmass there is a little quartz, orthoclase, and biotite. A few minute druses with terminated crystals of the groundmass projecting into them are filled with calcite. Long apatite fibers or needles penetrate across all the minerals of the rock.

**METAMORPHISM**

All of the rocks have been deformed and recrystallized, and the foliation and lineal structure are in whole or in large part dependent upon this.

**Metagabbro.** Within the metagabbro there are all gradations from a more or less massive variety showing relics of an ophitic or diabasic texture to amphibolite completely recrystallized and strongly foliated. The more massive weakly foliated rocks may also show very extensive recrystallization. The recrystallized rocks or portions of the rocks consist of polygonal-shaped grains of labradorite, pyroxene, and hornblende, the mafic minerals usually in little lens-shaped granular aggregates or strung out along the foliation planes and lineal structure or, in the case of the pyroxenes, as granulated border zones to the relics of primary grains. Where relics of the unrecrystallized rock are present, the labradorites are clouded with inclusions, and the recrystallized plagioclase grains are clear and fresh. Biotite where present is usually in aggregates of reddish brown grains. Garnet occurs almost wholly as euhedral grains associated with the recrystallized
grains of labradorite. Locally there are coarse dactylic intergrowths of augite and labradorite. In the more highly foliated rocks the mafic minerals and the labradorite may all be in elongate grains oriented parallel to the foliation or lineal structure. In these rocks the hornblende is a pleochroic olive green to yellow variety rather than the brown variety. A common facies is one in which the recrystallized labradorite is in approximately equidimensional grains, whereas the hornblende and pyroxene are in elongate grains oriented in the plane of the foliation. As previously described the garnet, although it does not usually occur as reaction rims, is, nevertheless, thought to be the result of a recombination of primary constituents since the garnet-bearing facies have a lower percentage of plagioclase and magnetite and a different hornblende from the nongarnetiferous rocks.

As an example of a rather massive variety with indistinct foliation, the olivine gabbro (5525) seven-tenths of a mile north of School 7 will be described. It shows relics of an ophitic texture. The primary labradorite crystals are clouded with inclusions. Their borders are recrystallized to polygonal grains of clear fresh labradorite. The olivine often has a reaction rim of hypersthene and is a trifle altered to serpentine, but in general occurs as clear fresh grains. The augite and hypersthene in part form primary grains and in part recrystallized granular aggregates. The brown hornblende is wholly in granular aggregates. Small grains of green spinel are associated with the hornblende. Dactylic intergrowths of green spinel and hypersthene are common on the borders of the hypersthene grains. Spinel also occurs to a lesser extent in dactylic intergrowths with hornblende and with garnet. One example of a dactylic intergrowth of spinel and hornblende surrounded by a peripheral rim of garnet was noted. Spinel also occurs as relics in garnet and as recrystallizations in clear paths or areas of the primary cloudy labradorite. The garnet occurs as euhedral crystals almost wholly between the recrystallized labradorite grains but rarely within a labradorite lath. The accessory scapolite is in clear polygonal grains associated with the recrystallized labradorite or in clear paths across the cloudy labradorite.

Santa Clara Complex. The texture of all members of the Santa Clara Complex, as observed with the microscope, shows a granular aggregate of polygonal grains of feldspar and mafic minerals with the quartz in recrystallized leaflike form. The grain of the recrystallized feldspars averages in general between 0.4 mm and 0.8 mm. There are scattered larger grains representing relics of the original feldspars. Garnet is a common accessory mineral and occurs almost wholly as reaction rims around augite, hornblende, hypersthene, and
magnetite, but occasionally as isolated euhedral grains within plagioclase and as replacements along fractures passing through feldspar and pyroxene. The garnet shows a characteristic vermicular intergrowth of quartz, and the garnet aureoles are usually elongate parallel to the foliation. Titanite reaction rims occur occasionally around magnetite grains. Myrmekite is common, but usually present in only slight amounts. A reddish brown biotite locally replaces the pyroxenes. Rarely, local facies of the medium-grained pyroxene-hornblende quartz syenite show only a mortar structure. Such rock shows a high ratio of microperthite to oligoclase, whereas in the crushed recrystallized facies the ratio is about equal, strongly indicating unmixing during deformation. No garnet or biotite occurs in the slightly deformed rocks. The garnet, biotite, myrmekite and titanite are all undeformed and are interpreted as forming after the crushing.

The hornblende-pyroxene quartz syenite, including the streaked facies, shows a texture in which the grains have been granulated on the border, and the crushed material forming the groundmass constitutes one-fourth to three-fourths of the whole. The feldspars constitute most of the obvious granulated material. The quartz is in recrystallized leaves. The ferromagnesian minerals all have their long axes oriented parallel to the foliation. Some specimens show the results of slicing and granulation, and in others little or no obvious results of deformation can be seen. There appears to be no direct relation between the degree of alteration of the pyroxene to hornblende and the degree of crushing. In a few intensely mashed facies there has been some unmixing of the microperthite on granulation and recrystallization to form separate grains of microcline and oligoclase.

St Regis granite. In thin section, the texture of the St Regis granite is seen to consist of a granular aggregate of grains for the most part of fairly uniform size and of a character and relations to the larger grains commonly interpreted as resulting from crushing and recrystallization. The quartz is in isolated recrystallized grains or in elongate amoeboid-like forms, but not usually in flat leaves. The hornblende is in elongate grains oriented parallel to the foliation and lineal structure. A trifle myrmekite later than the deformation is present. Rarely and locally the granite shows only a trifle mortar structure.

Diabase dikes. The diabase dikes are entirely unmetamorphosed.
STRUCTURE
ANTICLINES AND SYNCLINES

The foliation taken in conjunction with the mode of distribution of the kinds of rocks suggests a number of close folded anticlines and synclines, as roughly indicated in figure 6. In the northwest the first two belts of metagabbro conform to the trough of the synclines, and the St Regis granite belts outcrop on the anticlines, although northeast of Pitcher pond granite also occurs in small volume in a trough. In the trough of the Mutton ridge syncline metagabbro again forms a major element, although here too there is much quartz syenite, which has angled across the metagabbro belt, dismembered it and taken the place of the metagabbro in the structure.

To the southeast of these structures the syenite-granite rocks of the Santa Clara Complex appear on the anticlines and the St Regis granite, with associated amphibolites, in the troughs; as, for example, southwest of Spring Cove and north and west of Lake Meacham.

At the south, the Jennings Mountain dome forms an outstanding and most significant structure. Three well-defined synclines, each with granite and associated amphibolite in the troughs, surround it. On the east is the Meacham Lake synclinorium with a north-south trend and north pitch; on the south (St.Regis quadrangle) the Brandon Hill syncline with an east-northeast trend and eastward pitch (on Brandon Hill) of 25°; and on the west of the Jennings Mountain dome is the Spring Cove syncline with a northeast strike and northeast pitch of 25°-30°. What happens north of the dome is completely obscured by glacial drift.

The coarse hornblende quartz syenite and granite of Black and Leboeuf hills on the east and of Blue mountain and Middle hill on the west appear to be two opposed limbs of the Spring Cove syncline.

The anticline striking northeast through Gile and Santa Clara has a northeast pitch of about 30° at Santa Clara.

AGE AND STRUCTURAL INTERRELATIONS OF IGNEOUS ROCKS

Metagabbro. The question has been raised by Cushing (1899, p. 98-117) as to whether there may not be gabbro of two ages in the northern Adirondacks, one occurring interbanded with the younger granite, the other occurring as lenses of massive character, in part with amphibolitized borders, or as dikes. As examples of the former, he cites the amphibolite associated with the granite around Dickinson Center (Moira quadrangle) and in Brandon and
Figure 6 Location of identified axes of folds. Full lines are anticlines; dashed lines are synclinal axes. Structure is based on foliation.
Dickinson townships; and as examples of the younger gabbros, the dikes cutting the anorthosites to the south of the Santa Clara area. Apparently the boss of gabbro shown in cuts along the railroad one and one-half to two miles above St Regis Falls is also included by Cushing with the younger group. At this locality a transition is shown between hyperite at the core and amphibolite studded with very large garnets near the borders. There are several lenses of massive gabbro exposed on the Santa Clara quadrangle, such, for example as those forming Bearcove hill, Bull hill, and Kary mountain within the syenite and granite belts. The writer has found, however, that such gabbros are definitely cut by an occasional granite pegmatite vein and probably by syenitic veins. No positive evidence of gabbro cutting either syenite or granite has been seen. In view of the evidence for transition between gabbro and amphibolite, the abundance of amphibolite included in the granite and syenite, the absence of gabbro dikes in either syenite or granite, and the presence of granite pegmatite veins and probably syenite in even the most massive gabbro, the writer believes that all the gabbro of this area is of but one age, and older than the syenite and granite intrusions.

The metagabbro is the oldest major rock in the area. Elsewhere in the northwest Adirondacks gabbro has been shown to occur predominantly as sills in the Grenville series and to have been folded with the latter (Martin, 1916, p. 96-108; Cushing, 1925, p. 34-38; Buddington, 1929, p. 82-86). The structural characters of the gabbro of this quadrangle are consistent with their interpretation as folded sills. The gabbro sheets must have formed the original framework into which the younger magmas were intruded, for it occurs as inclusions within the medium-grained Santa Clara syenite and the St Regis granite everywhere throughout the belt between the anorthosite massif to the south (St Regis quadrangle) and the unconformably overlying cover of Paleozoic beds to the north (Malone quadrangle).

Balk, (1932, p. 56) has proposed the hypothesis that certain gabbros of the Adirondacks have been derived from the same magma as the quartz syenite, as indicated by "the close association of the gabbros with basic hornblende-bearing phases of syenite, the amphibolite fringes which envelop most of the massive gabbros, and the common development of flow layers in the syenite rich in augite, hornblende, and biotite are believed to represent closely related features of one and the same process." In local belts in the Santa Clara area gabbro masses are associated with a basic facies of the syenite, similar to the conditions Balk described. But the great uniform belt
of gabbro in the north border of the quadrangle, with its extension across onto the Malone quadrangle, can not be regarded as a facies developed more or less in place from the same magma as the syenite, because the gabbro here is exclusively associated with the St Regis granite, which is much younger than the syenite as well as younger than the gabbro. This gabbro moreover is continuous with that associated with the syenite border facies of the Santa Clara Complex, and therefore all the metagabbro of this quadrangle is interpreted as a distinct intrusion earlier than either the syenite or gabbro. Elsewhere in the northwest Adirondacks (Martin, 1916, p. 54–61; Cushing, 1925, p. 34; Smyth and Buddington, 1926, p. 21, 22; Buddington, 1929, p. 82–86; 1934, p. 56–58), gabbro sheets of large size and older than the granite and syenite intrusives occur within the Grenville series and have been folded with it. The gabbros of the Santa Clara quadrangle are of similar character in composition, texture and structure to these sheets in the Grenville, and are here correlated with them. Inclusions of metagabbro occur within the St Regis granite and the border facies of the Santa Clara Complex, and the metagabbro is locally much injected by granite pegmatite veins.

Santa Clara Complex—a folded gravity stratified sheet. The interrelationships and origin of the members of the Santa Clara Complex present a most intriguing problem. The quartz syenitic intrusives of the Adirondacks have commonly been interpreted as facies of batholithic masses. Balk and the writer, however, have independently suggested that they may be phacoliths or sills. The writer, as a result of a study of the Diana syenitic complex some 50 to 75 miles to the southwest, suggested (Buddington, 1929, p. 86–94) that it might be interpreted as an isoclinally folded sill. A restudy of this complex for evidences of gravity stratification revealed relationships which, if not definitely suggesting the presence of such phenomena, are at least, so far present data go, adequately interpreted by this hypothesis (Buddington, 1934). Evidences of gravity stratification were accordingly sought for in the Santa Clara Complex and it is believed are found well exemplified in the Jennings Mountain dome.

The Jennings Mountain dome is outlined by the domical foliation exhibited by the members of the Santa Clara Complex between Meacham lake and the St Regis river with the core centering around Jennings mountain. The axis strikes in general about east-west. Successive rock belts from the outside in comprise (1) (1 and 1-a of map) medium-grained hornblende-pyroxene quartz
syenite (sp.g. 2.68–2.70) in part with included narrow bands of metagabbro and amphibolite with associated more mafic pyroxene-
hornblende syenite; (2) (3 of map) clean hornblende quartz syenite
(sp.g. 2.65–2.67) with coarse phacoidal structure and some asso-
ciated coarse biotite granite (sp.g. 2.62–2.65); and (3) (2 of map)
a core of pyroxene quartzose syenite (sp.g. 2.68–2.72).

The suggestion is advanced that the rock of the outermost belt
(medium-grained pyroxene-hornblende quartz syenite), where the
rock is not locally modified in the contact zone with amphibolite,
represents a relatively undifferentiated chill facies of the primary
magma. Its texture must have been, before metamorphism, much
finer grained than the primary very coarse texture of the rocks
forming the core (hornblende quartz syenite, biotite granite, and
pyroxene quartzose syenite) of the dome. The condition of inter-
banding of this border rock with amphibolite, as contrasted with the
absence of included country rock from the core of the dome, also
suggests that favorable conditions for chilling existed in this border
zone. There may have been some slight differentiation before or
during intrusion, so that the primary magma may have been some-
what more mafic and less quartzose than the present average
composition of the pyroxene-hornblende quartz syenite. The medium-
grained streaked and the more mafic facies of the pyroxene-
hornblende quartz syenite occurs exclusively in association with
included layers of amphibolite and lenses of metagabbro, and is
interpreted as a facies of the primary magma which was modified
in part as a result of phenomena dependent in some way upon its
mechanics of injection into the metagabbro country rock, and in
part as a consequence of disintegration and assimilation of country
rock. It is possible that a more mafic, less quartzose, primary
magma of an earlier stage of intrusion is also involved here.

The next belt (3), hornblende quartz syenite and biotite granite,
must originally have had a rather coarse texture with feldspar
crystals from one-half inch to an inch in length. There are no
inclusions of gabbro or amphibolite in this zone. These rocks are
interpreted as the light alkalic-siliceous and granitic portions, which
rose during the differentiation of the magma and accumulated
beneath the roof. The hornblende quartz syenite appears to grade
into the medium-grained hornblende-pyroxene quartz syenite above
and into the more mafic coarse pyroxene syenite below; but the
biotite granite is locally intrusive, or at least has relatively sharp
contacts against the other coarse members. None has been definitely
identified in the chill facies.
The hornblende-pyroxene quartz syenite of the core is as coarse as the hornblende quartz syenite, has on the average a higher specific gravity and likewise has no inclusions of gabbro or amphibolite. It is interpreted as a heavier differentiate of the primary magma which now is approximately represented by the chill facies.

More basic rocks would be expected to be found beneath the core of the dome, but are not yet exposed by erosion.

The hornblende quartz syenite of the belt through Blue mountain and Gile is similar to that through Leboeuf hill and Twin mountains. The strikes and dips indicate that the rock of these belts may represent opposed limbs of a syncline. The belt through Reeves and Little Hurd hills is formed by the contact chilled facies of the Santa Clara Complex, and is similarly comparable in every way to that through Cherry hill, and both overlie the hornblende quartz syenite. The nose of a major anticlinal axis is indicated striking northeast through Santa Clara, and it is around the core of this anticline that the hornblende quartz syenite is exposed.

The pyroxene-hornblende quartz syenite along its northwest border from Fayetteville to Twin ponds appears to cut across the metagabbro at a slight angle. From Twin ponds southwest to the western border of the area, it has cut out the metagabbro as a uniform mass by intruding and dismembering it in such fashion that many lenses and shreds of amphibolite occur throughout the syenite in this belt. Northeast of Lake Titus the crosscutting relationship of the quartz syenite is also well shown, for the foliation of both gabbro and syenite strike N. 50°–60° E., whereas the contact line is N. 35° E. Similar discordances between the strike of the foliation and the strike of the contact between two kinds of rock are shown southwest of Twin ponds.

On the hypothesis that the Santa Clara Complex represents a folded gravity stratified differentiated sheet, the following interpretation may be drawn. The magma which went to form the complex was intruded slowly over a long period of time into the gabbro sills while they were still relatively flat-lying or locally slightly folded, and followed their primary structure planes. Some slight folding may have accompanied the intrusion of the magma so that it had either a sill or phacolithic form with subordinate cross-cutting relationships. The early portion of the magma was intimately involved with the gabbro, cooled moderately rapidly, and assumed a medium-grained texture, but heated the zone of the intrusion. The main body of the magma was emplaced without coming in contact with the country rock and cooled slowly, so that the texture was very coarse. Either the main body of magma differentiated in place
into a light hornblendic or biotitic alkalic-siliceous upper portion and a more basic pyroxenic lower facies, or the successive surges of previously differentiated magma came in in such relationships as to yield a gravity stratified sheet. In either case the granitic facies moved relative to the underlying portion.

An alternative hypothesis would be that the complex is a batholith composed of a series of successive intrusions; pyroxene-hornblende quartz syenite, pyroxene syenite and hornblende quartz syenite with associated biotite granite, in this order. The structural arrangement of the successive intrusions, however, is not what might have been expected on the basis of general rules. In particular, it is peculiar for the hornblende quartz syenite and associated granite to so consistently come in between the coarse pyroxene syenite and the medium-grained pyroxene-hornblende quartz syenite and to be restricted to that position. If the hornblende quartz syenite and granite were distinctly younger intrusions, they might be expected to form sills or dikes locally within the older pyroxene-hornblende quartz syenite or the metagabbro. Normally the more felsic facies of a batholith forms the core, rather than an intermediate ring as in the Jennings Mountain dome. It can not be said to be impossible or even improbable, however, for the arrangements of the facies as they are found on the Santa Clara quadrangle, to belong to a compound batholith.

Decision between the two hypotheses must await detailed knowledge of relationships elsewhere in the Adirondacks.

St Regis granite. The writer has nowhere found clear-cut positive evidence of granite dikes in the quartz syenite, but pink granite pegmatite veins are found in the quartz syenite locally where the St Regis granite is near by. No dikes of syenite have been seen in the granite, nor anything to suggest that the syenite is younger than the St Regis granite. The large scale relationships of the St Regis granite and the Santa Clara Complex are such as to strongly suggest that the former is intrusive into, and younger than, the latter. South of Long pond the St Regis granite is in contact with quartz syenite, which constitutes the northwest limb of the Santa Clara anticline. To the southwest the border of the granite angles across the limb of the anticline until it comes in contact with the coarse phacoidal Santa Clara hornblende quartz syenite and granite west of Dexter lake (Nicholville quadrangle) and nearer the core. The folded structure, if such it be, of the Santa Clara Complex thus antedates, at least in part, the emplacement of the St Regis granite at its present site.
At Cheney hill the St Regis granite also contains a big synclinal block of the Santa Clara hornblende quartz syenite.

The crosscutting relationships of the St Regis granite to the older rocks, although very important, are, however, not the predominant type of structural relation exhibited by the granite toward the country rock. The foliation of the granite is predominantly conformable with that of the metagabbro and amphibolite bands which it includes and with the structural anticlines and synclines indicated by the foliation of the Santa Clara Complex. In the northwest it occurs on the anticlinal cores with respect to the metagabbro, and in the south and east it is found, with some associated amphibolite and metagabbro, in the synclinal troughs with respect to the Santa Clara Complex. The writer therefore draws the conclusion that in considerable part the intrusion of the granite has been guided by the preexisting folds which tended to yield and open up along their foliation planes during this epoch of magmatic invasion. The flowage planes in the consolidating magma were thus developed in conformity with those of the deformed gabbro and Santa Clara Complex. Except for the crosscutting relationships previously discussed, the mechanics of intrusion for the St Regis granite was in large part of a "phacolithic" or a pine tree stromatolithic type, with some large scale transgressive contacts. For the most part the granite is intrusive along the structural planes of the metagabbro, and not along those of the Santa Clara Complex.

Whether the granite was intruded during a late stage of the period of deformation which folded the older rocks, as appears often to be the case in other regions, or whether the granite came in at a definitely later second period of deformation, has not yet been ascertained.

The St Regis granite has a microstructure which suggests considerable granulation and recrystallization under stress. Locally also the mixed gneisses, consisting of interleaved granite and amphibolite, are strongly crumpled and even crenulated.

**Diabase dikes.** The youngest intrusions in the region are the diabase dikes. As has been stated, they are most common in the Precambrian of the Malone quadrangle and the northern third of the Santa Clara area, and become sparse toward the south and southwest. These are part of a very widely extended system of dikes, referred on structural and lithologic grounds to the Keeweenawan period of the Precambrian. They occur mostly in a belt along the eastern and northern edges of the Adirondack massif (Hudson and Cushing, 1931, p. 81-113). West of the Santa Clara and Malone quadrangles, the belt in which dikes are common is covered by
Paleozoic beds. Dikes are again exposed, however, in the vicinity of Ganonoque on the St Lawrence river (Smyth, 1894), and are found prevalent in eastern Ontario (Wilson, 1925, p. 397-98), and west to beyond the Lake Superior region (Moore, 1929).

In the Santa Clara area they strike exclusively between N. 60°–80° E. This is similar to those of the Lyon mountain (Miller, 1926, p. 61), Ausable (Kemp and Alling, 1925, p. 63), and Lake Placid quadrangles (Miller, 1919, p. 61).

**FOLIATION AND LINEAL STRUCTURE**

Two fundamentally opposed hypotheses have been developed by geologists working in the Adirondacks to explain in large part the origin of the foliation and lineal structure of the igneous rocks, aside from that resulting from interpenetration or assimilation of an older rock. The earlier workers, including Kemp, Cushing, Smyth and Newland, believed that regional orogenic stresses played a very large part in producing and controlling the foliation within the igneous rocks as we now find them, although recognizing that there may have been an earlier primary structure of magmatic origin. Miller (1916), on the other hand, advocated the hypothesis that the foliation of the igneous rocks was primary and formed by flowage with concomitant crushing during the progress of intrusion and consolidation of the magma under the impulse of the efforts of the magma to shoulder aside blocks of Grenville gneiss. Balk has similarly more recently further developed the idea that the movement of the magma during intrusion was itself responsible for the induction of the foliation and lineal structure.

Balk (1932, p. 24–26) adopts this hypothesis and suggests that the reason why individual layers differ in the proportions in which the minerals are present is the "specific form resistance," one mineral offering more resistance than another to the liquid moving along its surfaces. Such differential movement (p. 36) "will favor the growth of layers of uniform composition, but uniform in the sense of uniform surface retardation and uniform rate of motion rather than uniform mineral composition. Both features, however, coincide closely in nature." In rocks for which an hypothesis of sill or phacolithic intrusion is proposed, the writer believes that the force of gravity should also be accorded a place as a factor in producing the orientation of the mineral grains, the broad scale banding, and locally a small scale sorting of minerals. The relative specific gravities of minerals must also play a part in the sorting of minerals due to differential flowage.
The following excerpts discussing foliation and lineal structure of the rocks of the Newcomb quadrangle are taken from Balk (1932, p. 28-29):

If magma moved along a retarding surface which was approximately even, and if the rate of movement along the wall was approximately the same in all directions parallel to the wall, foliation only would have resulted. . . . If, finally, magma moved along an even surface, but if the rate of movement in one direction was appreciably greater than in all other directions, then both foliation and flow lines would have originated. The latter will point in the direction in which the movement of the magma was fastest. In every case the flow lines indicate the longest axis of Leith's strain ellipsoid (C. K. Leith, 1923, p. 21). . . . Both the foliation and the flow lines are primary structures; that is, have originated during the time of the final magma consolidation, and not later. . . . The exact time when foliation and flow lines originated can be brought into relation with the magmatic differentiation. In the syenite series both structures were definitely developed before the syenite magma produced pegmatites and before myrmekite was developed. . . . Although of essentially the same age, the flow lines have continued to form after the foliation was completely developed.

Under the hypothesis adopted by Balk, the differentiation exhibited by masses such as the Santa Clara Complex would have taken place either before or coordinate with the emplacement of the magma. If the hypothesis of gravity stratification in place is adopted to explain the differentiation of the Santa Clara Complex, then the crushing and development of secondary foliation could still have taken place before the complete consolidation of the magma complex; and it is possible, though distinctly more difficult, to fit most of the phenomena into a scheme where the deformation is directly the result of continued magma pressure, magma pulsations and magmatic flowage.

There are, however, certain features in the Santa Clara quadrangle, and others in areas to the southwest, which suggest that the older ideas of regional orogenic stresses must again be considered. Where strong magmatic foliation is involved, it is commonly parallel to the borders. Yet it has previously been described how in the Santa Clara area the strike and dip of the foliation remain the same on each side of boundary lines whose trends are at an angle to the foliation, as along the boundary between the St Regis granite and the Santa Clara Complex in the northwest, and between the quartz syenite and metagabbro northeast of Lake Titus.

Again, a study of the arrangement of the strikes and dips of the foliation and of the lineal structure, plotted on the geologic map,
shows that they are systematic and essentially independent of the kind or age of country rock. The gabbro, the members of the Santa Clara Complex and the St Regis granite, all show an orientation of foliation and lineal structure appropriate to the portion of the area and the structure in which they occur. To explain this consistency in orientation of foliation and lineal structure in all these rocks on the basis of magmatic flowage necessitates a uniformity in direction of movement of magmas throughout widely separated periods which it is difficult for the writer to accept. The hypothesis that the metagabbro masses and Santa Clara Complex were originally gravity stratified sheets would involve their having had originally a primary banding, but whether they likewise possessed a primary lineal structure is a question. So far as the writer’s knowledge goes, gravity stratified sheets which have not been subsequently strongly deformed show but little of the kind of crushing which wholly characterizes the rocks under discussion.

The writer has previously described (1934) evidence from quadrangles to the southwest which seems to imply that stresses of regional orogenic character were effective in deforming the members of a granite-syenite complex similar to the Santa Clara. In that complex (the Diana complex) dikes of metadiabase cross the major large-scale banded structure, show pronounced chill zones against the country rock, and are themselves crossed by the same foliation and lineal structure as that of the inclosing rock. Furthermore, the microstructure of this complex can be traced continuously gradationally from a type of coarse recrystallization to one of fine ultra-mylonite, which it is difficult to believe could have been formed in anything but a solid. These phenomena, therefore, all suggest deformation of the Diana complex in a solid state.

In the Santa Clara quadrangle also the foliation and lineal structure affect most of the pegmatite veins as well as the major intrusives. A pronounced lineal structure developed in a quartz syenite pegmatite is well shown in the small road cut about a mile north of McColhum School, and both the granitic pegmatite veins and the gabbro in which they occur, in the southeast corner of the Malone area, are locally plicated together and have a consistent lineal structure. The deformation of many of the pegmatite veins as thus found in this region is in contrast to the conditions described by Balk for the central Adirondacks where they are later than the foliation.

Locally, however, in the Santa Clara quadrangle there is a distinct difference in the degree of deformation of the country rock and of the pegmatite veins. This is well shown in the road metal quarry north of Ward pond. Here the country rock is a mafic syenite,
showing in thin section the usual granulated character. Parallel to the foliation are seams of more quartzose pegmatitic nature which, both in the field and in thin section, show little or no evidences of deformation. They carry considerable magnetite, some pyrite, and rarely apatite. Rare quartz veins likewise show no signs of deformation. This type of relationship definitely favors Balk's hypothesis that the formation of foliation and lineal structure in the syenitic rocks was accomplished before the complete consolidation of the magma and the development of the pegmatite stage. Were it not that the pegmatitic seamed syenite seems definitely to have had a development in contact zones only and therefore presumably during the period of magma consolidation, the hypothesis might be put forward that part of the pegmatitic seams were of palingenetic origin, developed by vapors from the St Regis granite, locally effecting a metamorphic differentiation and coarsening of crystallization. The writer admittedly has at present no wholly satisfactory explanation for this phenomenon, on the hypothesis of deformation in the solid state.

The mere parallelism of the foliation in all these masses might be attributed to successive inheritance by the younger intrusions of a structure common to the older members, as a result of successively more or less parallel intrusion and sill or phacolithic structure. But the unity of the lineal structure is not thus so readily explained. It is a structure which, as it now occurs, is the result of dynamic crushing with some recrystallization and is related to the structural folds which affect all the major rocks. The writer is very doubtful of the possibility that the Santa Clara Complex could have been to any degree still unconsolidated at the time of intrusion of the St Regis granite; and the possibility becomes still less probable that the gabbro was still partly unconsolidated at this time.

The garnet of the metamorphosed metagabbro disappears at contact with the St Regis granite as though it were of earlier age. It therefore seems probable that the foliation and lineal structure of the metagabbro and rocks of the Santa Clara Complex were formed wholly before or in advance of the intrusion of the St Regis granite batholith. Deforming stresses of the same general nature and orientation, however, also effected a metamorphism of the St Regis granite and many of its pegmatites. The deformation of the granite may have been accomplished before complete consolidation, but the earlier rocks were solidified before their metamorphism. Under such an interpretation, the lineal structure of these rocks can not of itself necessarily indicate the lines of flowage during magmatic emplacement,
as has been suggested by Balk for the intrusives of the central Adirondacks.

The hypothesis that the foliation and lineal structure of the metabasalt and the Santa Clara Complex, so far as they are connected with the crushing, granulation and concomitant recrystallization, are the result of effectively plastic flow in the solid state, appears to explain more satisfactorily most of the phenomena than one of its development as a result of purely magmatic flowage. The secondary structures are superimposed on, and conformable with, whatever primary banding and foliation may have developed during the emplacement of the rocks and their consolidation.

JOINTS

Throughout the quadrangle, regardless of the kind of rock, the strike of the foliation, or the strike of the local lineal structure, the joints strike predominantly in two general directions; one set within the range N. 60°–90° E., and the other N. 5° E. to N. 25° W. The dip is usually greater than 70°, and may be either north or south in the case of the east to east-northeast joints, and either east or west in the case of the north to north-northwest joints, although more usually west. Locally, as on Ragged Mountain ridge and in the vicinity of Middle, West and Reeves hills, there is a set of prominent joints with a strike of N. 50° W. or N. 60° W. A few joints occur in other directions.

The basalt dikes occur exclusively within the east-northeast fractures and strike N. 60°–80° E.

There is only one place in the quadrangle where a set of joints at right angles, and apparently definitely related, to the lineal structure has been noted. On Ragged mountain the lineal structure strikes S. 30°–40° W. and a pronounced set of cross joints strikes about N. 50° W., but dip steeply both to the northeast and southwest. In the vicinity of Black hill there is a set of joints about at right angles to the lineal structure and with a dip steeply to the east where the pitch of the lineal structure is horizontal or gentle west. The joints at this locality, however, are in the same direction as the regional set of joints and can not be proven to be necessarily related to the lineal structure. This relationship occurs at a few other local areas in the quadrangle.

Joint systems developed during the cooling and consolidation of the gabbro and Santa Clara Complex would have been destroyed during the subsequent deformation, crushing, and flowage of the rocks after their crystallization. The present major joint systems
are regional in character, and are independent of the kind of rock or the local structures.

**ECONOMIC GEOLOGY**

No mineral deposits of economic value have been found on the Santa Clara quadrangle. A small prospect pit was sunk in the early days in search of iron ore on the south shoulder of Orebed mountain. The locality is now overgrown. The predominant rock of the mountain is granite, locally with thin amphibolite inclusions. The magnetite is in what looks like a green syenite and occurs merely as thin veinlets in the rock so far as specimens on the dump show.

Several quarries were opened up (their positions are indicated on the map) to obtain road metal for the construction of the two main highways, but none was in active operation at the time of the present survey.

Several gravel pits are being operated for road repairs and general purposes. One lies about one and one-half miles southwest of Santa Clara and is in the north portion of the Santa Clara delta near the kame portion. The kames, kame areas and their vicinity in general appear to afford the most likely places for gravel deposits.
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