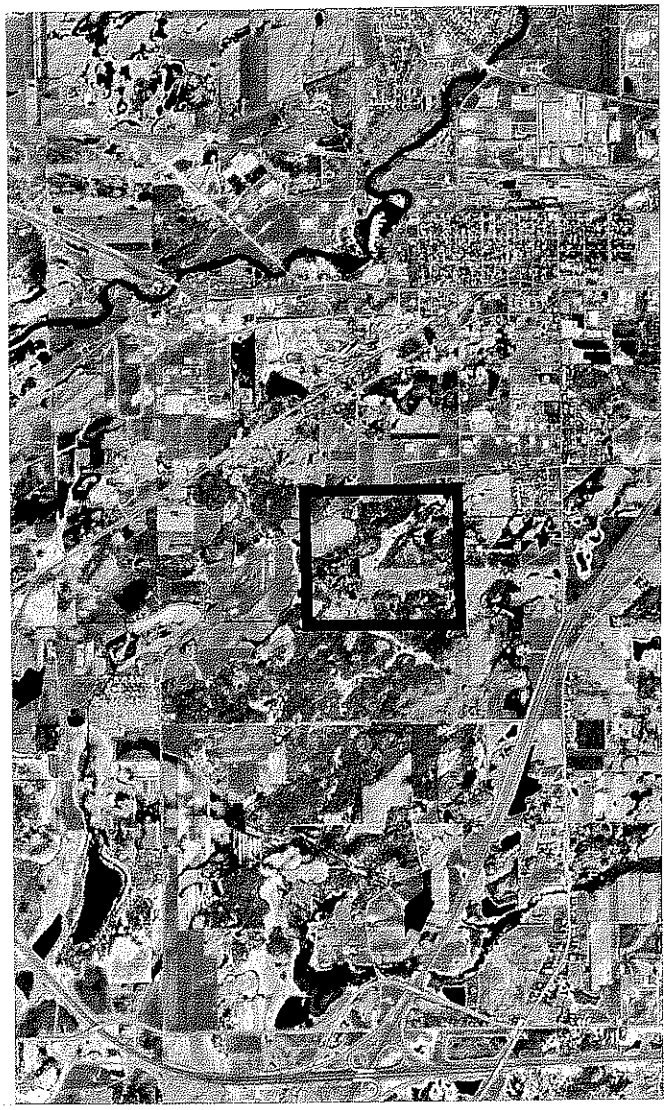
Geology Around Quarry Park



The cover shows a high altitude photograph of the area around Granite Quarry Park. The general location of the park is shown by the box. A linear feature that marks a probable bedrock fault is marked by the short arrows.

FINAL REPORT

GEOLOGY

OF THE

NEIGHBORHOOD

AROUND

GRANITE QUARRY PARK

by

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June, 1994

This report is designed as a summary for non-geologists. It is based upon data in a more comprehensive, technical final report that is available in the Stearns County Park Department after December, 1994.

INTRODUCTION

Every special place has its own essence or innate "sense" that grows not only from its present condition, but is also deeply rooted in its past. This "essence of place" can be appreciated using spiritual and aesthetic approaches, but it can also be delineated using the techniques of traditional science. The more we become familiar with a place and the more we understand about the physical environment, the easier it becomes to love that special place.

Granite Quarry Park is such a place. It will take more than a series of maps or a simple listing of attributes to describe the park. A complete description requires documentation of the web of interrelationships that exists among rocks, water, air, plants, animals, and humans in this special place. And, it requires an interpretation of the history of these interrelationships.

The "special" nature of the park has a dual aspect. First, this place is **unique**. For example, extensive outcrops led to intensive quarrying and the abandoned quarry holes eventually were used for recreation. Unique attributes have contributed to the "essence of place". But, the park is also important because it is **representative** of the wide variety of conditions that characterize central Minnesota. For example, rocks that outcrop in the park extend into other areas and scientific investigations within the park may lead to a better understanding of the larger area.

In this report on the geologic neighborhood of Granite Quarry Park we will review background information, describe the geology of eastern Stearns County based on previous work and publications, and discuss the twenty-five square miles surrounding the park in some detail. Four maps were produced as a part of the current work and the large plates are available in the Park Department. The maps describe surface geology of young glacial sediments and the configuration and geology of older, buried rocks. We will show that patterns in the oldest crystalline bedrock are repeated vertically and influence the geology of overlying material. This means, for example, that the mineralogic variations in granite which once influenced quarrying operations and that the ground water "plumbing systems" in fractures which have modern environmental significance, are controlled by events that happened long ago, in the dim geologic past. Whatever Granite Quarry Park is today, is the result of this ancient geologic history.

BACKGROUND: PARK LOCATION

In central Minnesota all major biologic environments in the state come together. Pine forests from the northeast are located near deciduous woods from the southeast and both merge and are marginal with the open prairies of western Minnesota. In a similar fashion, the geology of central Minnesota has attributes representative of all areas of the state: crystalline igneous and metamorphic bedrock is similar to occurrences in northeastern Minnesota; sandstone, shale, and limestone are thin and limited, but thicken and become more continuous to the southeast and west; and glacial and stream deposits cover bedrock throughout the state. Human activities in central Minnesota also reflect statewide patterns; urban extensions from the Twin Cities area are surrounded by more pervasive rural influences. The area is representative of the total state, eastern Stearns County is representative of central Minnesota, and Granite Quarry Park serves to illustrate all of these interdependences.

Patterns in bedrock geology in eastern Stearns County are similar to those observed in the twenty-five square-mile "neighborhood" around the park. The twenty-five square-mile study area is located in T.124N., R.28 and 29W. Patterns in the neighborhood maps are similar to those within the park, which is located in parts of sections 19 and 20, T.124N., R.28W. Thus, aspects of the park are repeated and enlarged in the surrounding area and aspects of the surrounding area provide a context for the park. Granite Quarry Park does not exist in a vacuum; it is part of a continuous whole and reflects that setting. Figure 1 summarizes the geographic location of the park.

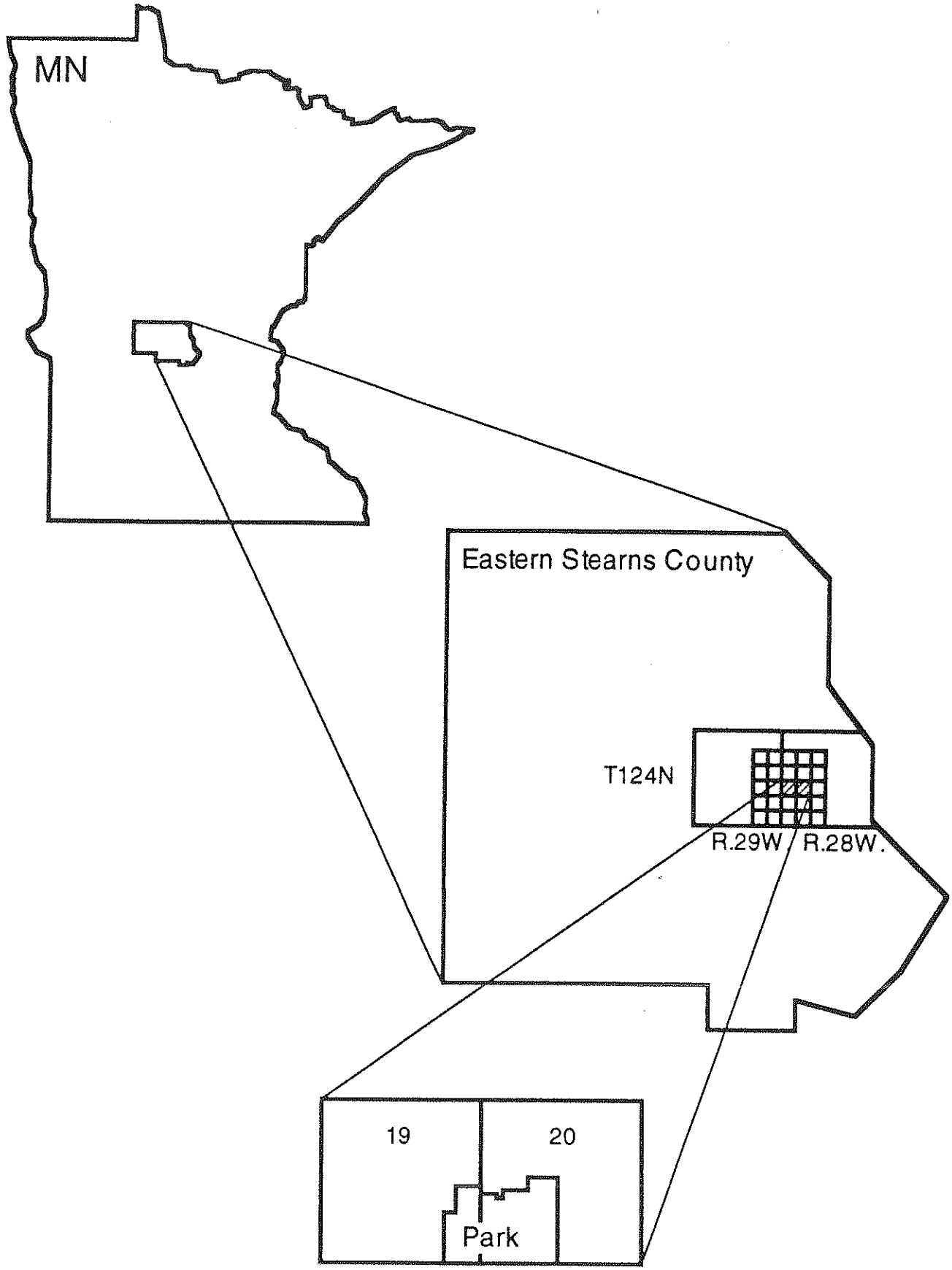


Figure 1--Map showing the location of Granite Quarry Park in eastern Stearns County and central Minnesota.

BACKGROUND: GEOLOGIC LAYERS

A generalized side view of the geologic layers in central Minnesota is shown in Figure 2. The view runs along the Mississippi River just east of Stearns County and provides a simplified summary of geologic time. The youngest material is unconsolidated clay, sand, and gravel which forms a continuous blanket over the area. This material is termed "drift" and it was deposited by glaciers and streams during the Quaternary Period (about the last one million years). The intermediate layer is discontinuous sedimentary rocks including weathered residuum, shale, and sandstone. These rocks were formed during the Cretaceous Period (about 60 to 120 million years ago) and during the Cambrian Period (about 500 to 550 million years ago). The deepest rocks are the oldest. Metamorphic and igneous rocks including granite, argillite, and graywacke were formed during the Precambrian (more than one billion years ago). The layer shown as "granite" also includes metamorphic gneiss. Although it is the oldest crystalline rocks that will be emphasized in these investigations, the other layers are also part of the park's geologic context.

The configuration and conditions on the earth's surface in part reflect the buried geology. For example, the high-elevation areas of thick drift generally correspond with areas of high-elevation bedrock. Also, bedrock tends to have lower elevations along the streams and drainages. Figure 2 only hints at interrelationships of this nature; they will be made more explicit as we examine the geology in more detail.

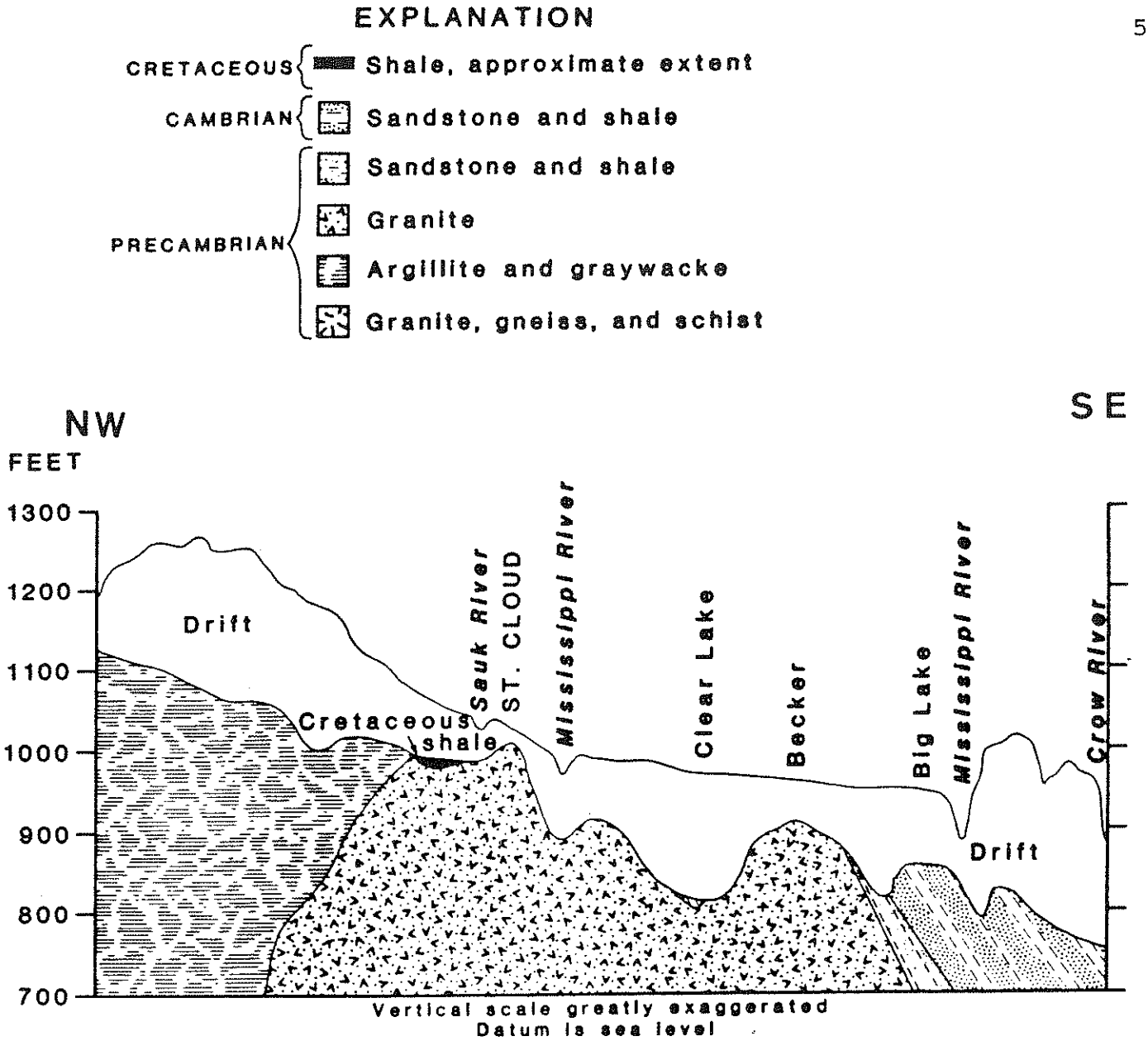


Figure 2--Simplified cross section showing geologic layers in central Minnesota along the Mississippi River. (Taken from Lindholm, 1980).

BACKGROUND: LOCAL DETAILED LAYERS

Another side view of the earth's geologic layers is shown in Figure 3. This shows more detailed subdivisions within each of the major layers and is located in eastern Stearns County near Granite Quarry Park.

The youngest layer of glacial drift includes material deposited directly by glacial ice (shown as open circles) and is called "till". The higher hills in the area are composed of till. In contrast, low flat areas are generally composed of material deposited by meltwater streams. This material is called "outwash" and is shown as dots in Figure 3.

The intermediate layer of sedimentary rocks is dominantly from the Cretaceous Period in the vicinity of the park. The Cretaceous was a part of the Age of Dinosaurs and the rocks consist mainly of clay and shale (units 1 through 5, Figure 3). Unit 3 is particularly noteworthy because it tends to be fairly continuous throughout the area and has a fairly constant elevation of about 1000 ft above sea level. The total Cretacous layer is thicker and has high elevations beneath areas of high surface elevations. It is also thicker and has low elevations near fault zones in the crystalline rocks. Ancient weathering of the crystalline rocks is also deeper along the fault zones.

The oldest and deepest layer is the Precambrian crystalline bedrock. In places igneous rocks penetrate metamorphic and other igneous rocks. In other places, the margins of these two rock types meet along fault zones. In general, the configuration of the top of the crystalline bedrock is an expression of the Precambrian geology: granitic rocks form knobs, metamorphic rocks have lower elevations, and fault zones are marked by linear areas of low bedrock elevation. It is the fabric and pattern in the Precambrian crystalline rocks that forms a template for later deposition, erosion, and faulting. Patterns in Cretaceous sedimentary rocks and in glacial till and outwash have been inherited from geometries produced in Precambrian rocks more than a billion years ago. It is the Precambrian crystalline rocks that are fundamental in our understanding of the geology around Granite Quarry Park.

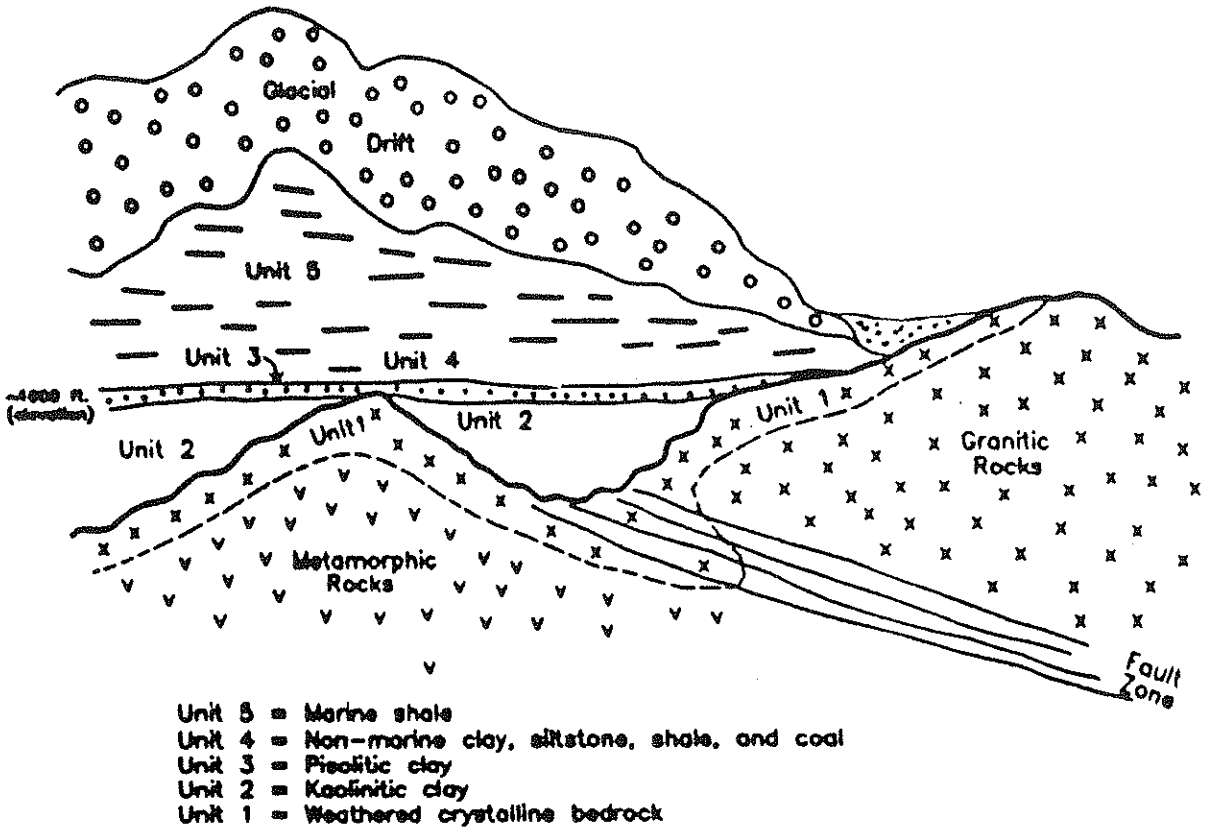


Figure 3--Cross section showing the details of geologic layers in eastern Stearns County near Granite Quarry Park. (Taken from Shurr and others, 1991).

EASTERN STEARNS COUNTY: BEDROCK GEOLOGY

In the next three figures, the geology of eastern Stearns County will be illustrated in progressively more detail and progressively closer to the park site. If all of the stream deposits and glacial drift were removed, then the resulting exposed surface of the bedrock would have the pattern of rock types shown in Figure 4. This map of bedrock geology was produced by integrating observations from outcrops and well records with maps of gravity and magnetic fields. The unpatterned Cretaceous rocks cover much of the area, especially to the south and west, but the Precambrian crystalline rocks are shown in some detail near the park.

The Precambrian rocks are subdivided into two broad categories: 1) Pre-Penokean metamorphic rocks and 2) Penokean granitic rocks. The term "Penokean" refers to the mountain building event which produced igneous and metamorphic rocks and associated geologic structures approximately 1.7 billion years ago. Among the metamorphic rocks, the Sartell and Richmond Gneiss are believed to be the oldest rocks in the area, while the Watab Amplibolite and St. Wendal Metagabbro are close to the age of the granitic rocks. All of these dark metamorphic rocks are in places similar in appearance to the gray Reformatory Granite. The younger red St. Cloud Granite has the Rockville Granite as a local subdivision.

All of these formal Precambrian rock units are named for localities in and near eastern Stearns County. The type areas which provide the names are shown as triangles in Figure 4. We will see later that the patterns of crystalline bedrock near the park are modified when examined in more detail. But, the regional patterns are adequately represented in Figure 4 and these patterns shown a systematic relationship to the configuration of the buried bedrock surface.

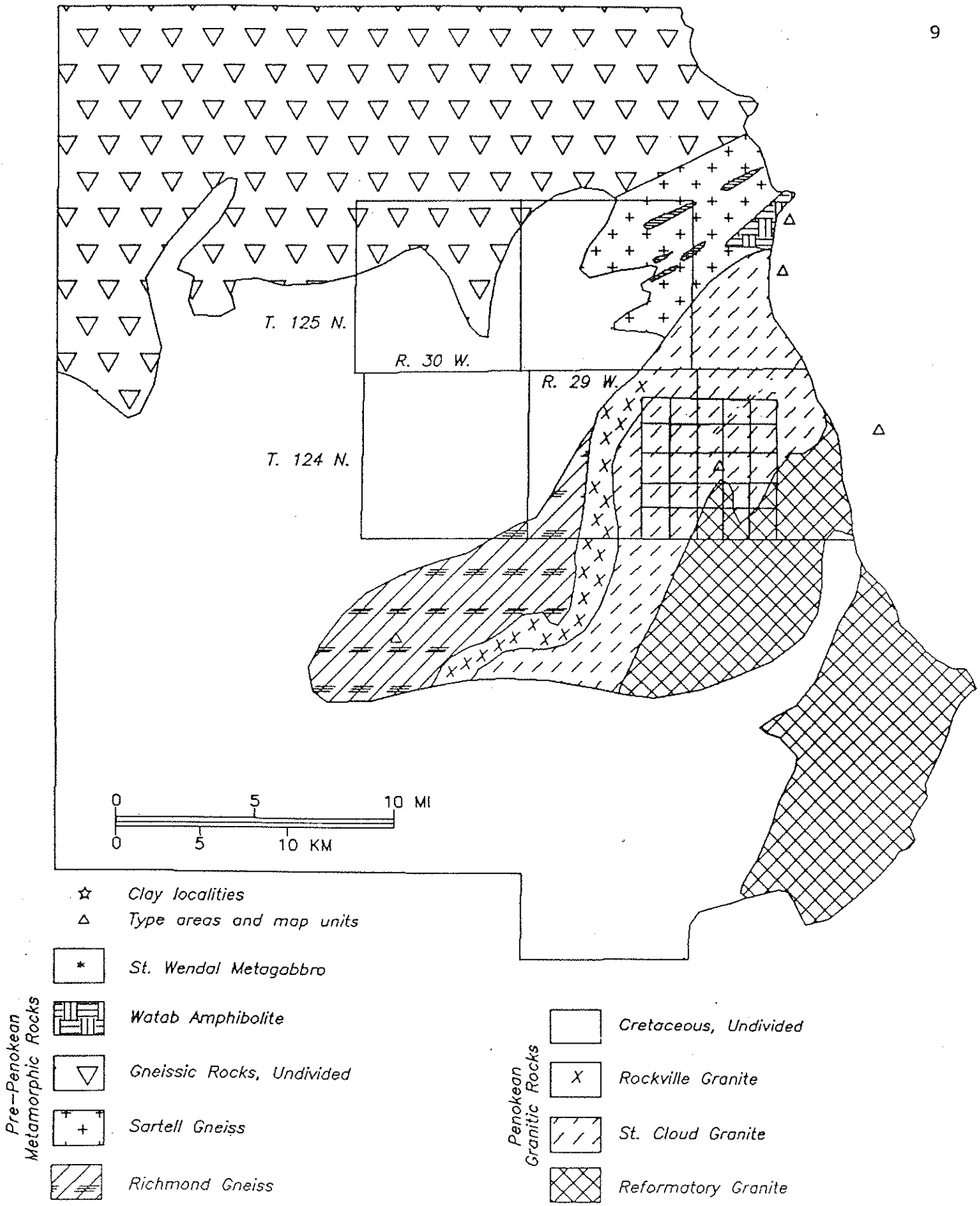


Figure 4--Map of bedrock geology in eastern Stearns County. (Modified from Morey and others, 1981).

EASTERN STEARNS COUNTY: SHAPE OF BEDROCK SURFACE

The shape of the buried crystalline bedrock surface in eastern Stearns County is shown in Figure 5. The curved lines show equal values of elevation above sea level and so the scattered wide, flat areas labeled "1000" or "1050" are higher than the linear low areas at "950" and "900". In effect the map is showing buried hills and valleys beneath the glacial drift and beneath the Cretaceous sedimentary rocks. Bedrock elevations from outcrops and well records were used to prepare the map. The straight lines superimposed on the map are linear features visible on satellite images.

The pattern of buried highs and lows is closely related to the pattern of bedrock geology. Granite Quarry Park is located on a large buried hill (A, Figure 5). This knob and others in eastern Stearns County (B through F, Figure 5) generally correspond with areas of granitic and gneissic rocks (see Figure 4). In contrast, the linear low areas (such as G, Figure 5) are associated thick with Cretaceous sedimentary rocks. These relationships between bedrock lows and thick Cretaceous rocks will be illustrated in more detail in the next figure. There are side views or cross sections marked by locations 1 through 6 and between localities SW and NE (Figure 5).

The linear features visible on satellite images generally parallel the lines of equal bedrock elevation. This means that the lines generally bound the areas of high and low elevation. For example, east-west linear features bound the east-west low area just north of Knob A. Another important example is the northwest linear feature between localities SW and NE on the west side of Knob A. This linear feature is just southwest of the park's southwestern boundary and probably marks a fault. Indeed, many of the linear features may mark fault zones. Figure 5 is significant because no faults have been shown on published maps in Stearns County. Linear features mapped on satellite images generally trend northwest, northeast, east-west, and rarely north-south. Similar orientations are seen in the bedrock lows. This suggests that faults in eastern Stearns County and within the park may have these trends.

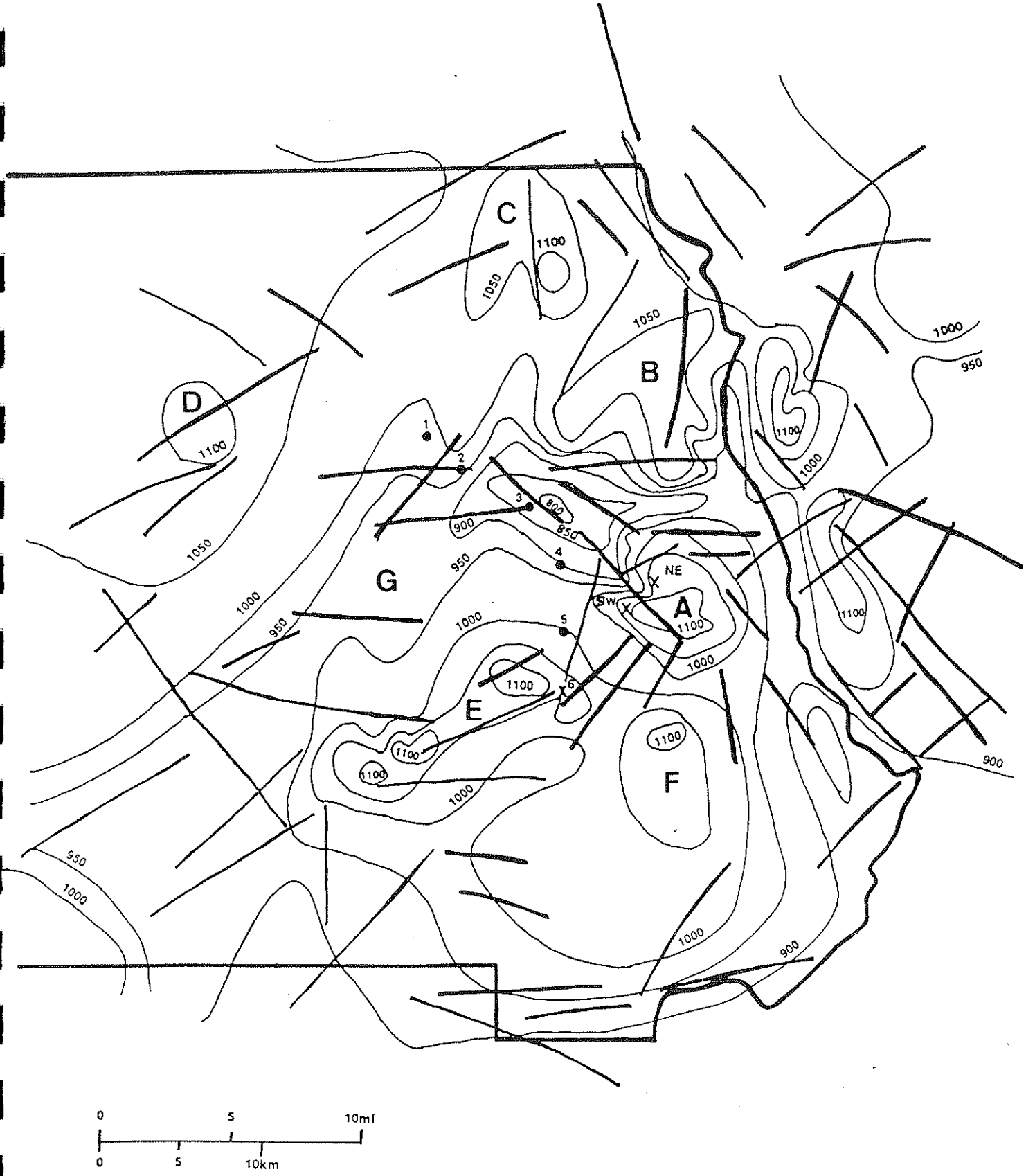


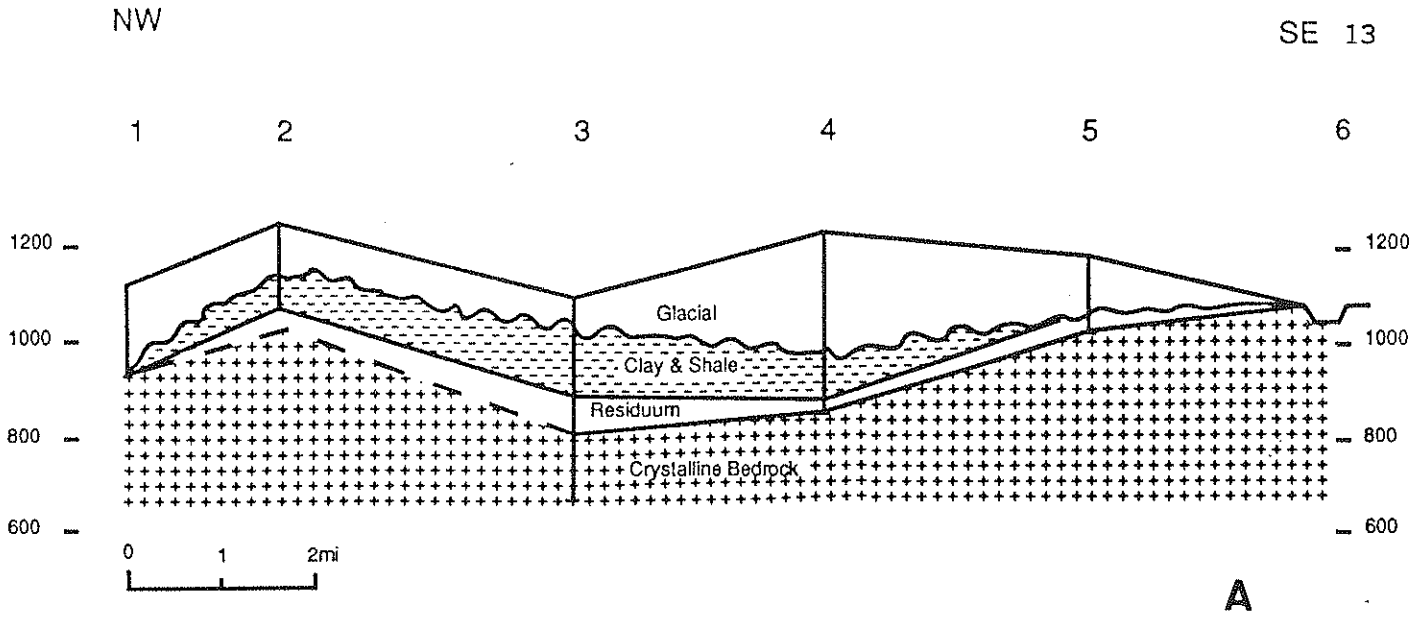
Figure 5--Map showing contours of equal elevation on the crystalline bedrock surface in eastern Stearns County. Straight lines are linear features visible on satellite images. (Modified from Shurr and others, 1991).

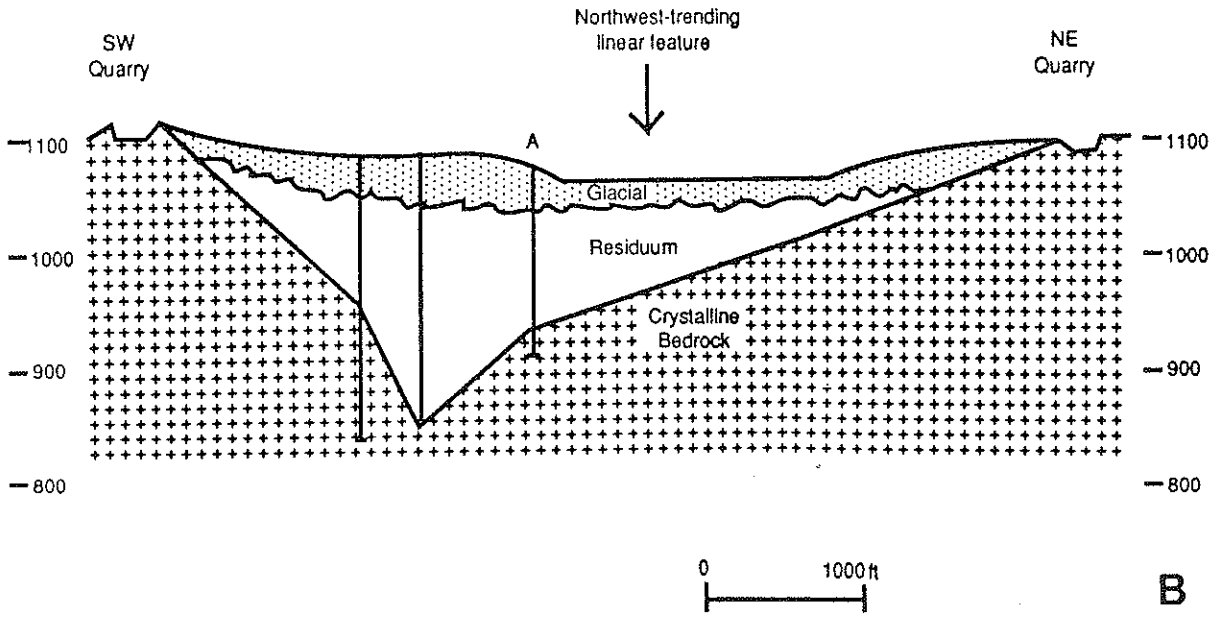
EASTERN STEARNS COUNTY: WELL RECORDS

Two side views of geologic layers interpreted from water well records are shown in Figure 6. Cross section A is longer and cuts across a deep, linear area of low bedrock elevations which trends northeast (G, Figure 5). Cross section B is shorter and gives the details of layers within the linear low trending northwest along the satellite line on the west side of Knob A (Figure 5). Both side views illustrate the relationships between Cretaceous sedimentary rocks and the shape of the crystalline bedrock surface.

Glacial sediments of varying thickness form the uppermost and youngest layer in each side view. Along cross section A, Cretaceous clay and shale overlie Cretaceous weathered residuum. All of these Cretaceous sedimentary rocks are thickest where the crystalline bedrock elevation is low and they become thinner onto the higher bedrock elevations to the northwest and southeast. In cross section B, the Cretaceous residuum is thick in the linear bedrock low between two quarries. This area of low bedrock elevation corresponds with the northwest-trending linear feature visible on satellite images and is located just southwest of the park.

These relationships between surface features, Cretaceous sedimentary rocks, and crystalline bedrock elevations in eastern Stearns County are significant because they are generalizations which are useful in the twenty-five square-mile study area surrounding the park. Because granitic or gneissic rocks tend to have higher elevations and faults or some metamorphic rocks have low elevations, these patterns can be used to interpret bedrock geology. Also, the interrelationships serve as specific examples of the linkages that exist between ancient crystalline bedrock, patterns in Cretaceous sedimentary rocks, and features visible on the surface in glacial drift and stream sediments.





Fdigure 6--Cross sections constructed from well records showing geologic layers near Granite Quarry Park. (See Figure 5 for locations).

A--Long section showing layers in the large linear bedrock low north and west of the park.

B--Local section showing layers in the linear low just southwest of the park that is marked by a linear feature visible on satellite images.

PARK NEIGHBORHOOD: SURFICIAL GEOLOGY

The next four figures illustrate the geology in the twenty-five square-mile area surrounding Quarry Park. We will start with a look at surficial geology which shows patterns in the young glacial and stream sediments around the park. Then we will look at the configuration of older buried layers and finally examine the bedrock geology surrounding the park. All of these maps are important because they continue the focus to progressively more detail within the park. More detailed versions of these four maps are available from the Park Department.

The map of surficial geology (Figure 7) is based upon interpretations of geologic parent materials from published soil maps for Stearns County. The several map units were compared with topographic maps and field-checked. In general, the map units are listed from youngest (water, saturated soil, alluvium) to oldest (outcrop of crystalline bedrock).

Outwash sand and gravel is the most widespread map unit. It is part of the extensive Anoka Sandplain and has higher elevations than the younger terrace sand and gravel along the Sauk River. Till deposited by glacial ice consists of poorly-sorted sand, gravel, and some clay. It is located at higher elevations in the western part of the area and is found in a large area within and to the south of the park. It is probably no coincidence that there are many outcrops also in this area; the till and bedrock at higher elevations were not significantly eroded or covered by the meltwater that deposited extensive outwash.

The youngest map unit (water, saturated soil, and alluvium) has some distinctive patterns that relate to the oldest map unit (bedrock outcrop). Elongate, linear saturated soil areas about one and a half miles south of the park (A, Figure 7) are on trend and correspond with the northeast linear low associated with the satellite linear feature (near A, Figure 5, and B, Figure 6). Similar linear wetlands (B, C, and D, Figure 7) surround the park and there are two small northeast-trending areas of saturated soil in the northern part of the park and just to the east. The next figure will illustrate that all of these linear areas of saturated soil correspond with linear areas of low bedrock elevation.

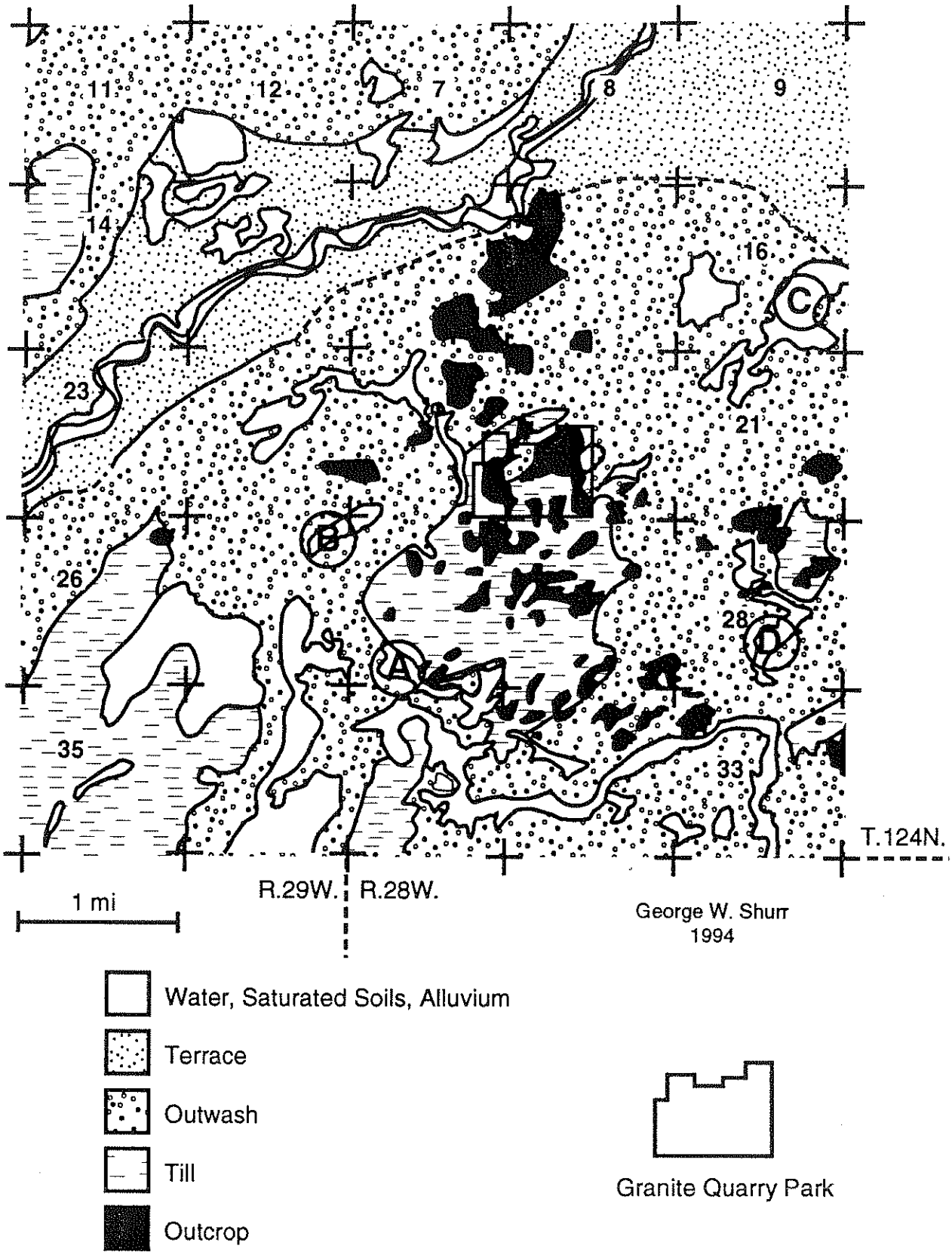


Figure 7--Surficial geology in the twenty-five square-mile neighborhood around Granite Quarry Park.

PARK NEIGHBORHOOD: CRYSTALLINE BEDROCK CONFIGURATION

The configuration or shape of the buried crystalline bedrock surface is shown in Figure 8. Lines of equal elevation are drawn to summarize elevation data obtained from 150 water well records, 50 outcrops, and 7 geophysical test sites. It is immediately obvious that the buried bedrock hill on which the park is located (A, Figure 5) is more complicated at this more detailed scale. Basically, the knob is flat at about 1100 ft elevation, but has linear low areas trending northwest and northeast. The highest crystalline bedrock elevation is in the northeastern part of the park.

Linear low areas surrounding the park knob (A, B, C, and D, Figure 8) correspond with linear areas of saturated soil (A, B, C, and D, Figure 7). In particular, northwest-trending area A corresponds with the satellite linear feature (near A, Figure 5, and B, Figure 6). Several other northwest linear lows are located north of the park. Immediately west of the park, a large linear low area trends northeast (B, Figure 8); smaller northeast linear lows are found within the park and just to the east. The southern part of the park is in a northwest-trending low area which is parallel to the linear feature visible on satellite images. The east-west low about one mile north of the park also corresponds with a satellite feature (Figure 5).

All of these coincident patterns are important because they demonstrate the interrelationships between several layers of geologic material. For example, it is interesting to note that the northeast trend of the Sauk River (Figure 7) and its associated terraces corresponds with the trend of bedrock elevation lines in that area (Figure 8). Many of the linear low areas discussed in the previous paragraph are probably related to faults in the crystalline bedrock. These illustrate the influence that ancient Precambrian structural patterns have had throughout geologic history.

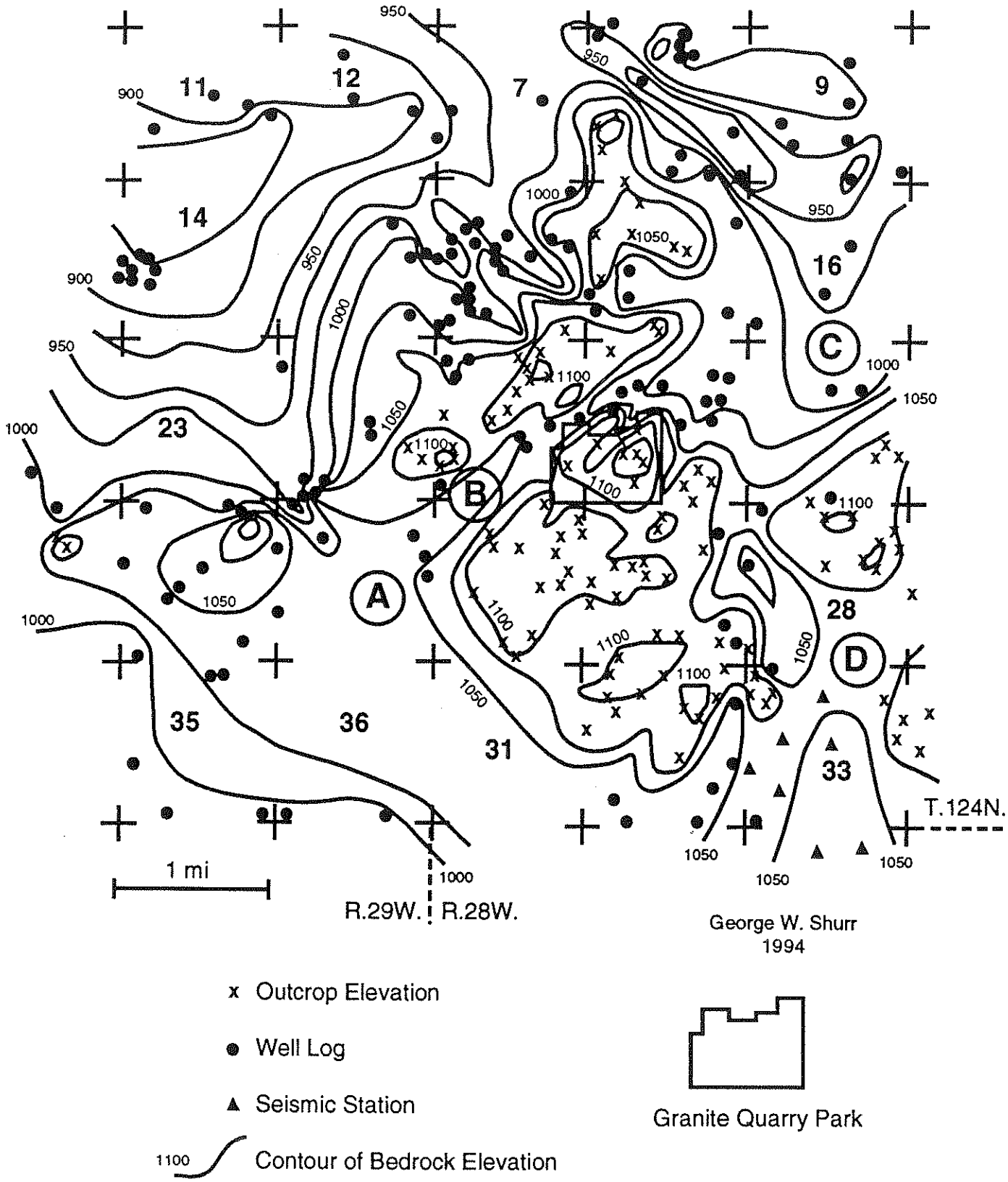


Figure 8--Lines of equal elevation that show the configuration or shape of the buried surface of crystalline bedrock in the neighborhood of the park.

PARK NEIGHBORHOOD: CRETACEOUS RESIDUUM CONFIGURATION

During the Age of Dinosaurs an ancient soil formed on the exposed surface of crystalline bedrock. This "paleosol" is preserved in the park neighborhood and eastern Stearns County as a distinctive clay layer (Unit 3, Figure 3). It is easily recognized by well drillers in the area and although there are no exposures of the paleosol in outcrop, the well records provide enough information to produce a map of elevation on the old residuum surface (Figure 9).

In general, the lines of equal elevation on the surface of this Cretaceous weathering residuum do not show as much variation as those on the surface of the crystalline bedrock (Figure 8). This means that there is less relief on the residuum surface. That is the same as saying the hills are lower and the valleys less steep on this buried landscape. The largest of the northwest and northeast linear low areas on the crystalline bedrock surface (Figure 8) have some expression on the residuum surface (Figure 9). For example, the northeast trend along the Sauk River to the northwest of the park does show on Figure 9. The smaller northeast low area just northwest of the park also has expression.

Elevations on the Cretaceous residuum are most often at or below 1050 ft. Above 1050 ft, little residuum is preserved and the crystalline bedrock surface is relatively unweathered. In these areas the weathered residuum has probably been removed by erosion. It is thicker in the areas where the crystalline bedrock elevations are low. These are areas postulated to be faults as shown in the generalized sketch in Figure 3. Again, the patterns on the ancient buried landscape that was formed during the Age of Dinosaurs, are controlled by a template of geologic structures and rocks in the even older Precambrian crystalline bedrock.

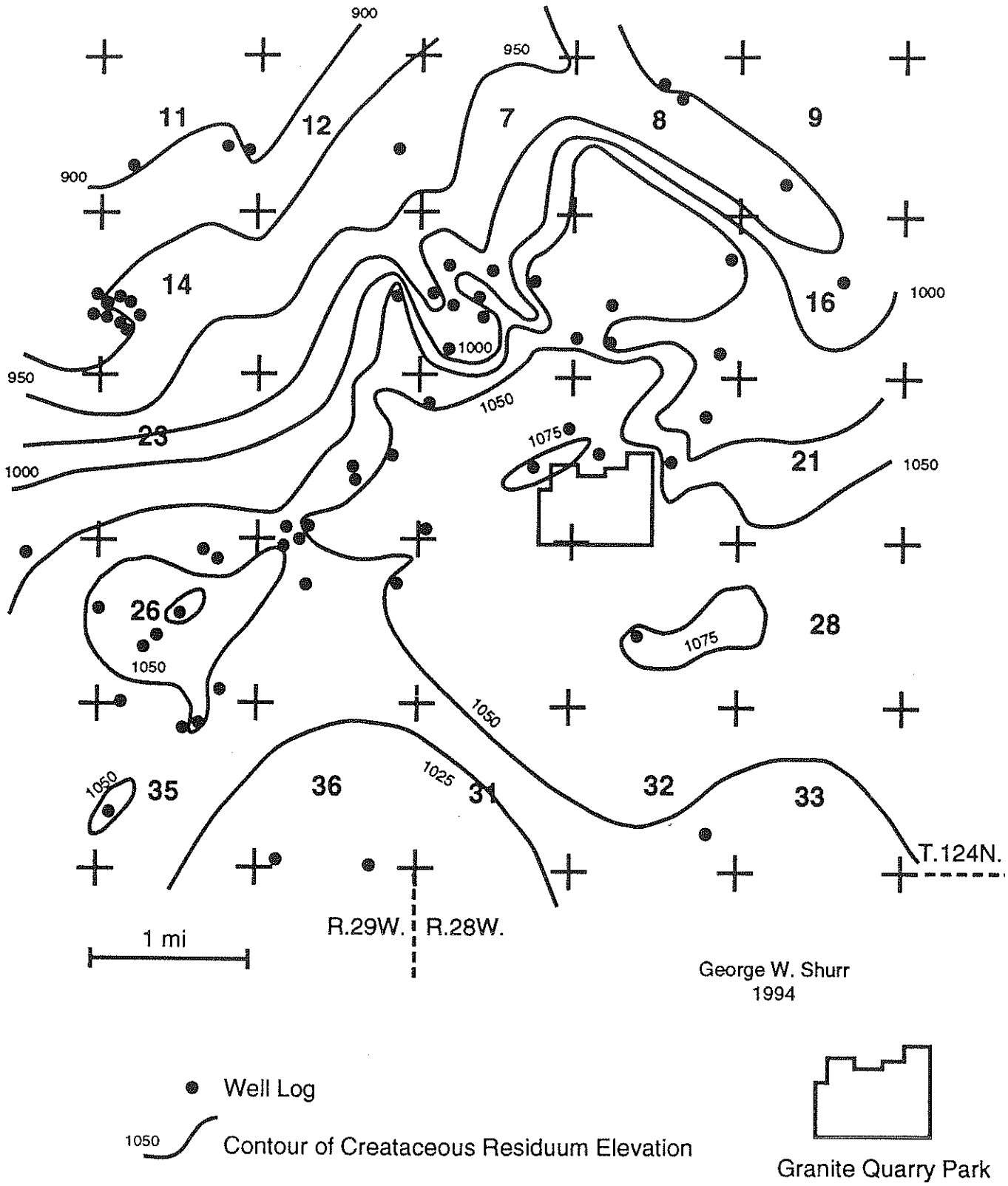


Figure 9--Lines of equal elevation that show the configuration of the buried Cretaceous "paleosol" (see unit 3, Figure 3) in the neighborhood of the park.

PARK NEIGHBORHOOD: BEDROCK GEOLOGY

If all overlying glacial and stream sediments were removed, the pattern of bedrock geologic units would be as shown in Figure 10. This map is similar to the less detailed map of eastern Stearns County (Figure 4); however, some modifications have been made. The Cretaceous sedimentary rocks are more extensive in the local map and the red St. Cloud Granite is much less extensive. Rockville Granite is now recognized near the park and dark metamorphic rocks are included with gray Reformatory Granite.

Comparing the configuration map (Figure 8) with the geologic map (Figure 10), it is clear that Cretaceous sedimentary rocks occupy the lower elevations. Areas of granitic rock tend to have higher elevations. Well-defined and postulated faults are also found along the linear low areas. Of particular note is the northwest-trending fault just south of the park; there is a clear offset of the line between the red St. Cloud and gray Reformatory Granites. Northeast faults located north of the park also have clear expression. Several small faults within the park are too small to show on this map.

The St. Cloud Granite has a distinctive "wishbone" shape that is probably related in part to the northeast-trending faults. The main mass is separated from a small area of red to the north and an area of Rockville Granite is found along the west margin. The red St. Cloud and Rockville Granites are totally surrounded by the gray Reformatory Granite and dark metamorphic rocks. The dark map units trend north-south through the center of the park and separate areas of red granite in the eastern and western parts of the park.

It is obvious from these "neighborhood" maps, that Granite Quarry Park includes outcrops which document important geologic relationships. Intensive study of the well-exposed bedrock within the park should provide significant insights into the geologic history of central Minnesota.

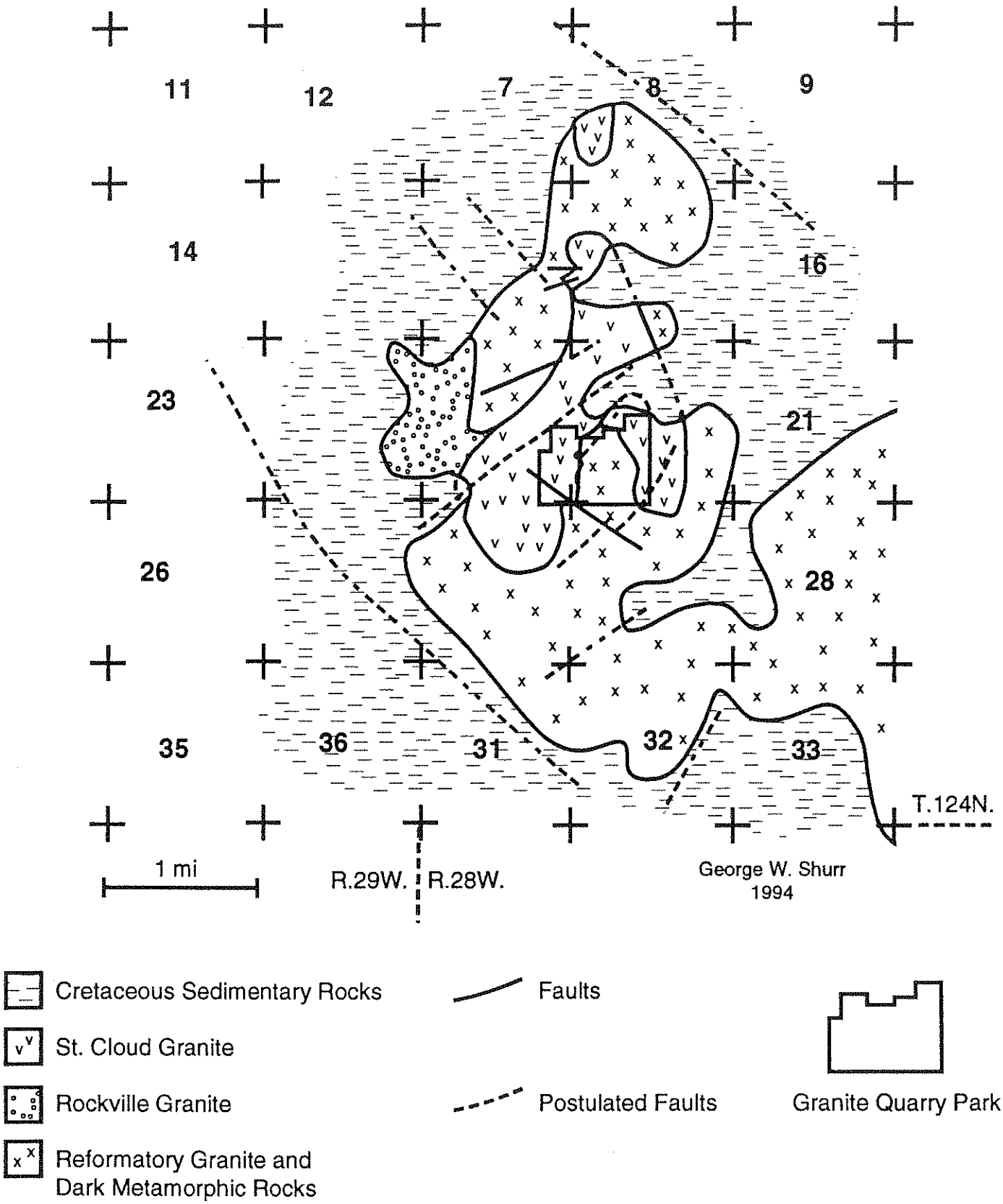


Figure 10--Map of bedrock geology in the twenty-five square-mile neighborhood around Granite Quarry Park.

INTERPRETATION OF GEOLOGIC HISTORY

We have seen that patterns in surface materials and buried sedimentary rocks are closely related to the geology of ancient crystalline bedrock. The history of glaciation and stream activity in the area, was therefore influenced by the underlying bedrock as well as by climatic variations. Similarly, sedimentary rock deposited during the Age of Dinosaurs records a history that depends as much on the geology of the crystalline bedrock as on changes in sea level and tropical climatic conditions. Fundamentally, it is the ancient Precambrian geologic history which is reflected in subsequent events throughout geologic time.

The idea of plate tectonics is a modern expression of an earlier notion termed continental drift. Plate tectonics is a summary of global earth movements which visualizes continental "lithosphere plates" rifted or torn into smaller pieces. These plates drift laterally to stick together on accreted margins where oceanic crust bends down into the mantle and mountains are formed adjacent to oceanic trenches. The Andes Mountains on the west side of South America are the classic example, but the idea has application in interpreting Precambrian geologic history in central Minnesota.

Figure 11 summarizes a plate tectonic interpretation for central Minnesota. As much as 2 billion years ago there was an ocean closing to a smaller size as volcanic island arcs, accreted arcs and continental fragments migrated northwest toward the rifted continental margin of the Superior Craton. Eventually the mass moving from the southeast, thrust over the continental margin to produce the fold and thrust belt now recognized in the area of the Cuyuna Iron Range and around Lake Mille Lacs. Finally, granites in the St. Cloud area south of the fold and thrust belt were formed to "pin" the pile of faulted slabs and end this Penokean mountain building event. Much later (at about 1 billion years ago) the continental lithosphere again rifted to reactivate older faults, produce new faults, and add basaltic rocks to the dominantly granitic rocks in central Minnesota. These Precambrian crystalline rocks and structural patterns subsequently influenced geologic events all the way to the present day.

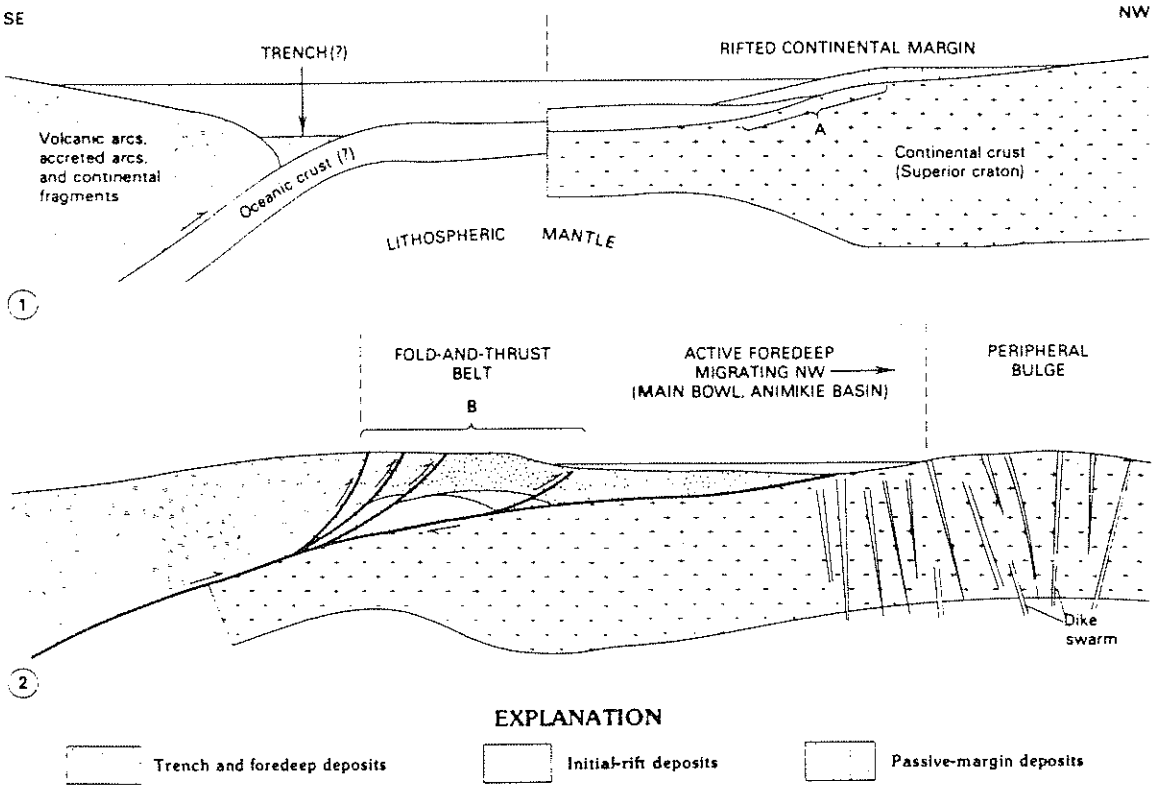


Figure 11--Interpretation of Precambrian place tectonic history in central Minnesota (Taken from Southwick and Morey, 1991). Upper cross section (1) shows initial closing along the continental margin and lower cross section (2) shows the eventual upthrusting associated with the "docking" of the accreted terrains.

CONCLUSIONS

Ancient Precambrian rocks and zones of weakness provide a fundamental "tectonic template" which can be used to understand a wide variety of geologic processes through a long span of time. Granite Quarry Park preserves and illustrates these important rocks and structures, but in addition it provides perspective on more recent human activities in the area.

Many decades ago, the park area was bustling with a busy granite industry. Resource development continues in the general area; both crushed aggregate and large-block quarrying could benefit from studies carried out on the park site. Within the past ten years, the park site was proposed as a study area for the disposal of hazardous and radioactive waste. More recently, urban development pressures have increased dramatically around the park. A clear picture of the total geologic environment in the park will help avoid potentially dangerous environmental problems. In the future, recreational programs on the site will have important augmentation by the existence of on-going technical research activities. Ultimately, Granite Quarry Park may stand as one of the earliest and most complete examples of quarry reclamation leading to coequal recreation and scientific investigation. Current conditions in the park represent only one "snapshot" in a long time continuum.

All of these relatively recent scenarios of human activity in the park are the result of the very ancient geologic history preserved in the bedrock record. Resource development, environmental problems, and general human interaction with nature are all related to patterns of fracture, crystal size and shape, and mineral composition in the bedrock. It is the ancient geologic history that defines the modern "essence of place" in Granite Quarry Park.

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