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MINERALOGIC DISPERSAL PATTERNS IN THE VANOSS FORMATION, SOUTH-CENTRAL OKLAHOMA

A DISSERTATION

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JOHN BYRON THOMAS

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MINERALOGIC DISPERSAL PATTERNS IN THE

VANOSS FORMATION, SOUTH-CENTRAL

OKLAHOMA

APPROVED BY

Harvey Blatt

Patrick K. Sutherland

[illegible]

[illegible]

Theodore R. Walker

DISSERTATION COMMITTEE

DISSERTATION

MINERALOGIC DISPERSAL PATTERNS IN THE VANOSS FORMATION, SOUTH-CENTRAL OKLAHOMA

One-hundred forty-seven samples of the Permo-Pennsylvanian Vanoss Formation of south-central Oklahoma were collected for purposes of determining mineralogic dispersal patterns from the Arbuckle Mountains. Light mineral, heavy mineral and clay mineral fractions were examined to evaluate their value in indicating such dispersal patterns as well as the effect of diagenesis on the Vanoss mineralogy.

There appear to be two principal source areas, based primarily on the light mineral evaluations. An igneous source apparently located near T. 3-4 N., R. 5-6 E. is best shown by distribution maps or trend maps of granitic detritus; specifically granite rock fragments, microcline-perthite, total feldspar and polycrystalline quartz. The source rocks were presumably Precambrian granites which presently are exposed 28 miles south of the indicated source area. This source, however, appears to be structurally unlikely based on present tectonic information.

A second source area is predominantly carbonate and friable sandstone located along the southern boundary of the Vanoss outcrop belt on the north side of the Arbuckles. The greatest floods of clastics seem to have come from the highland region located in T. 2-3 S., R. 1 W., as evidenced by the distribution of limestone and chert rock fragments and also overgrown quartz grains.

Without knowledge of the mineralogy of the igneous source rocks for comparison, interpretation of the petrology of the Vanoss Formation would lead to misconceptions about the geologic history of the unit. The non-opaque heavy mineral suite composed of predominantly ultra-stable zircon, tourmaline, rutile and garnet strongly indicates sedimentary or metamorphic sources for the Vanoss. Heavy minerals present in the Precambrian granite source rocks are not unique to granites and are common in metamorphic rocks. A metamorphic source is further indicated by the high concentrations of albite-twinned plagioclase (Slemmons, 1962) but this is due to disintegration of the coarser, simple Carlsbad twins during transport.

The original clay mineralogy of the Vanoss Formation has been largely obliterated by the diagenetic reconstruction to kaolinite with vestiges of the original suite present only in more argillaceous portions of the formation.

In future studies of clastic rocks where source areas are not exposed for comparison, recognition of the mineralogic limitations pointed out by this study should lead to fewer misconceptions concerning the accuracy of provenance determinations of sandstone units.

ACKNOWLEDGMENTS

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MINERALOGIC DISPERSAL PATTERNS IN THE VANOSS FORMATION, SOUTH-CENTRAL OKLAHOMA

INTRODUCTION

Numerous papers dealing with provenance and dispersal aspects of clastic sedimentary rocks include rather detailed descriptions of source areas. The authors of these papers (e.g., Krynine, 1950; Courdin and Hubert, 1969; and Folk, 1960) make statements about source area, mineralogy, paleoclimate and rate and amount of uplift based on the petrology of the clastic rocks studied.

The intent of this investigation is to compare the petrology of an ancient clastic sedimentary rock unit to that of its exposed, nearby source terrain. By means of examining the light mineral, heavy mineral and clay mineral fractions of the sedimentary rock sequence, I hope to determine the accuracy with which the petrology of a source area can be reconstructed from the petrology of the sediments derived from it.

According to Ham (1969) and others, the Permo-Pennsylvanian Vanoss Formation is a clastic wedge deposit shed from the Arbuckle Mountains in south-central Oklahoma. Nearly 17,000 feet of Late Cambrian through Mississippian sediments (Ham, 1969, p. 19) in the Arbuckle geosyncline were welded onto the stable craton.

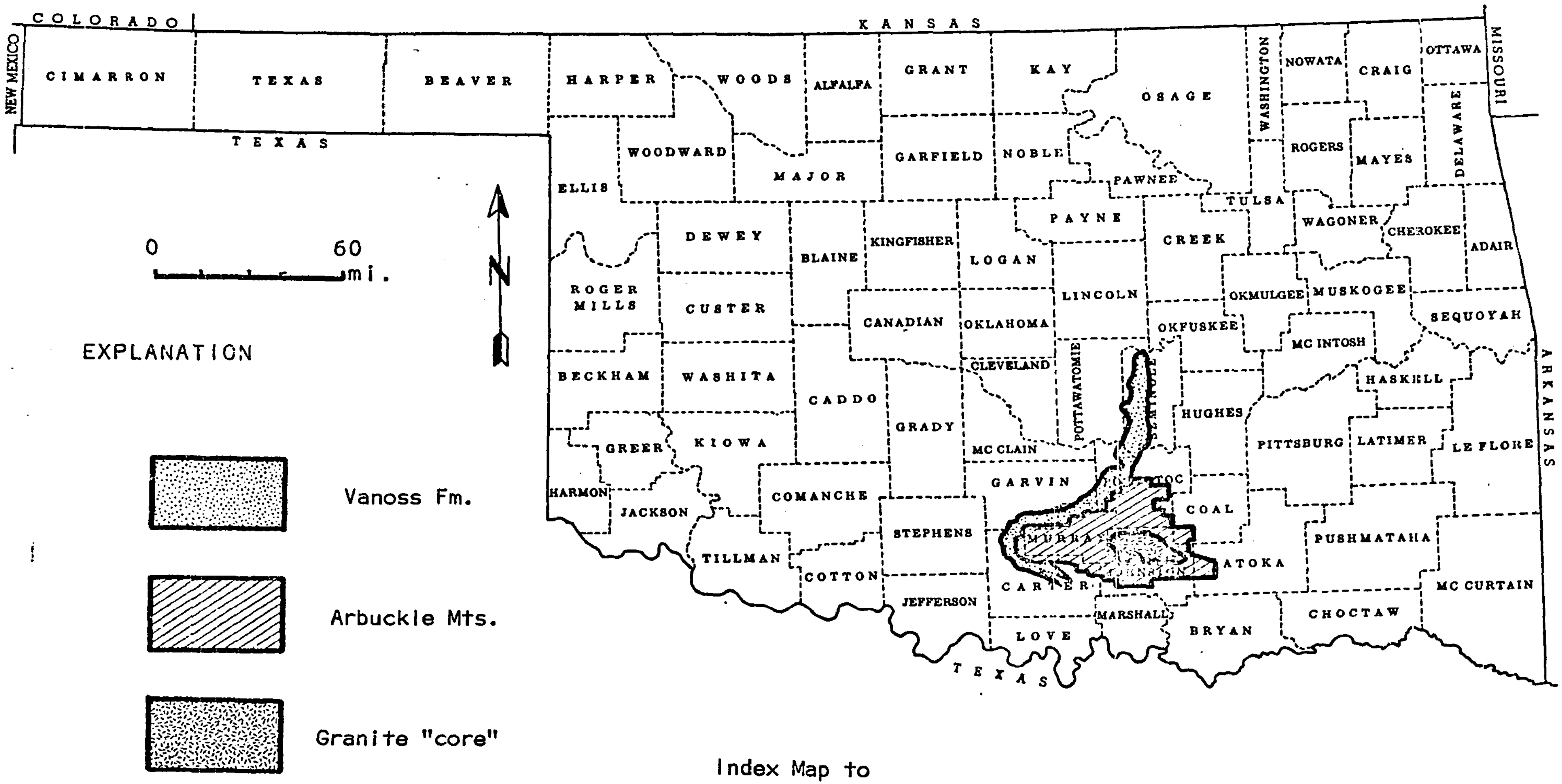
This was accomplished by means of several orogenic pulsations in late Pennsylvanian and Permian time. Each pulse is marked by deposition of a conglomerate. The oldest conglomerate, the Deese Formation, is Desmoinesian in age and contains much younger clasts than the Vanoss Formation (Virgilian-Wolfcampian) because the uplifted sediments were being pared-down through successively older strata. Not until Vanoss deposition began was the igneous core of the Arbuckles exposed for erosion.

Area of Investigation

The Vanoss Formation is exposed north of the Arbuckle Mountains. As a blanketing apron of limestone and arkosic conglomerates, it strikes approximately east-west along the mountain front but shifts to a north-northeast trend in the area north of the town of Sulphur (Secs. 33-35, T. 1 N., R. 3 E. and Secs. 2-4, T. 1 S., R. 3 E., Murray County, Oklahoma). The change in strike corresponds to a change in the dominant lithology, from limestone and arkosic conglomerate to feldspathic and nonfeldspathic friable silicate sandstones interlayered with fissile multicolored shale. The regional dip of 1 to 2 degrees is generally westward or northwestward but steeper dips are present locally in association with small-displacement faults in the coarser-grained portions of the formation.

The area studied includes all or part of Johnston, Murray, Garvin, Pontotoc, Pottawatomie and Seminole counties in south-central Oklahoma. Included are portions of T. 2 S. through T. 11 N., and R. 1 W. through R. 6 E. (see fig. 1).

The topography is generally an undulating plain eroded by



Index Map to

Area of Investigation.

Figure 1

Rock Creek, Buckhorn Creek, the superposed Washita River and South Fork of the Canadian River and numerous other intermittent streams. Principal drainage direction is toward the south-southeast. Low-lying escarpments are formed in areas where the clastics are better indurated. Interspaced are shallow valleys developed on weaker friable sandstones and shales. Thornbury (1965) places this area in his Osage section of the Central Lowlands Physiographic Province. As the Pennsylvanian and Permian rocks of the area are parallel in strike, the area has also been termed the Prairie Plains homocline by King (1951).

The area has a maximum relief of approximately 450 feet. Rocks of the Vanoss Formation occur at elevations ranging from about 1,300 feet to 880 feet. Greatest local topographic relief is in excess of 250 feet, found in the Dougherty 7.5-minute Quadrangle, T. 1-2 S., R. 3 E., Murray County, Oklahoma, where the folded Lower Paleozoic rocks have been incised by the Washita River drainage system. The maximum elevation of 1,335 feet, however, does not occur in the same area but in the E 1/2, NE 1/4, Sec. 33, T. 2 N., R. 4 E. (Sulphur North 7.5-minute Quadrangle) approximately two miles southwest of the community of Roff, Oklahoma.

Previous Investigations

The Vanoss Formation was named by Morgan (1924, p. 133) for arkosic rocks that crop out at the community of Vanoss in the N 1/2, Sec. 3 T. 4 N., R. 4 E., Pontotoc County, Oklahoma. He reported the total thickness of the Vanoss to be between 250 and 650 feet but recognized the possible intergradation of three lithologically similar formations, the Vanoss, Stratford and Konawa Formations. He included these in a time-transgressive series of alternating arkosic sandstones, conglomerates, varicolored shales and limestones termed the Pontotoc Terrane, estimated to be 1,000 to 1,580 feet thick (Morgan, 1922, p. 4).

Morgan recognized the local source area for the granitic and sedimentary material making up the Vanoss strata studied in the Stonewall Quadrangle and stated (1922, p. 4):

> Proximity of the series to the mountain mass and the close similarity between the feldspars in the arkose and those in the igneous rocks of the mountains constitute sufficient evidence to justify this conclusion. In addition, the presence in the series of fragments and pebbles of limestone which by their contained fossils may be identified as belonging to limestones outcropping in the Arbuckles would apparently leave no room for doubt . . . [that the source of most of the material was the Arbuckle Mountains].

Birk (1925), based on mapping predating Morgan's report on the Stonewall 30-minute Quadrangle, stated that the Vanoss was continuous around the western end of the Arbuckle Mountains. His conclusions were founded on being able to trace the contact between the overlying basal Hart limestone member of the Stratford Formation and the presence of coated pebbles, also described by Morgan in the type area. These pebbles may be oncolites or caliche balls.

Brief lithologic descriptions of Vanoss strata as they appear in Garvin (Dott, 1930), Murray (Melton, 1930), Pontotoc (Conkline, 1930), and Seminole (Levorsen, 1930) Counties were parts of a special Oil and Gas Bulletin (no. 40) published by the Oklahoma Geological Survey in 1930. Only Levorsen's work, however, included thickness values for the Vanoss, 250 to 520 feet (1930, p. 292).

Dunham (1951) studied Pennsylvanian conglomerates in the Lake

Classen area southwest of the town of Davis, Oklahoma (T. 1-2 S., R. 1 W. and 1-2 E.). His work was the first detailed study of the Vanoss since that of Morgan and Birk and established the tectonic setting for the Vanoss which later appeared (1955) in an enlarged report incorporating the work of Ham, McKinley and others (1954).

A regional geologic map of the Arbuckle Mountains (Ham, McKinley and others, 1954) was the first to recognize two members of the Vanoss Formation as it appears on the northern flank of the Arbuckles. The basal conglomerate member and overlying shale member of the Vanoss unconformably overly sedimentary rocks of widely varying ages (Ordovician through Lower Pennsylvanian) as a blanket with slight westward dip. Only in the southernmost outcrops was any significant dip noted, as mentioned earlier.

Tanner (1956) conducted a detailed reinvestigation of the geology of Seminole County. He suggested the highly variable thicknesses of Vanoss reported by Morgan, for example, might be due to several possibilities: (1) thinning northward by nondeposition, (2) miscorrelation of the beds marking the formational boundaries, (3) changes northward in lithofacies and (4) thinning northward as sediments were deposited on higher elevation surfaces. He did not mark the base of the Vanoss at the first appearance of arkosic sediments above the Ada conglomerate as Morgan did and says of the Vanoss in Seminole County (1956, p. 105):

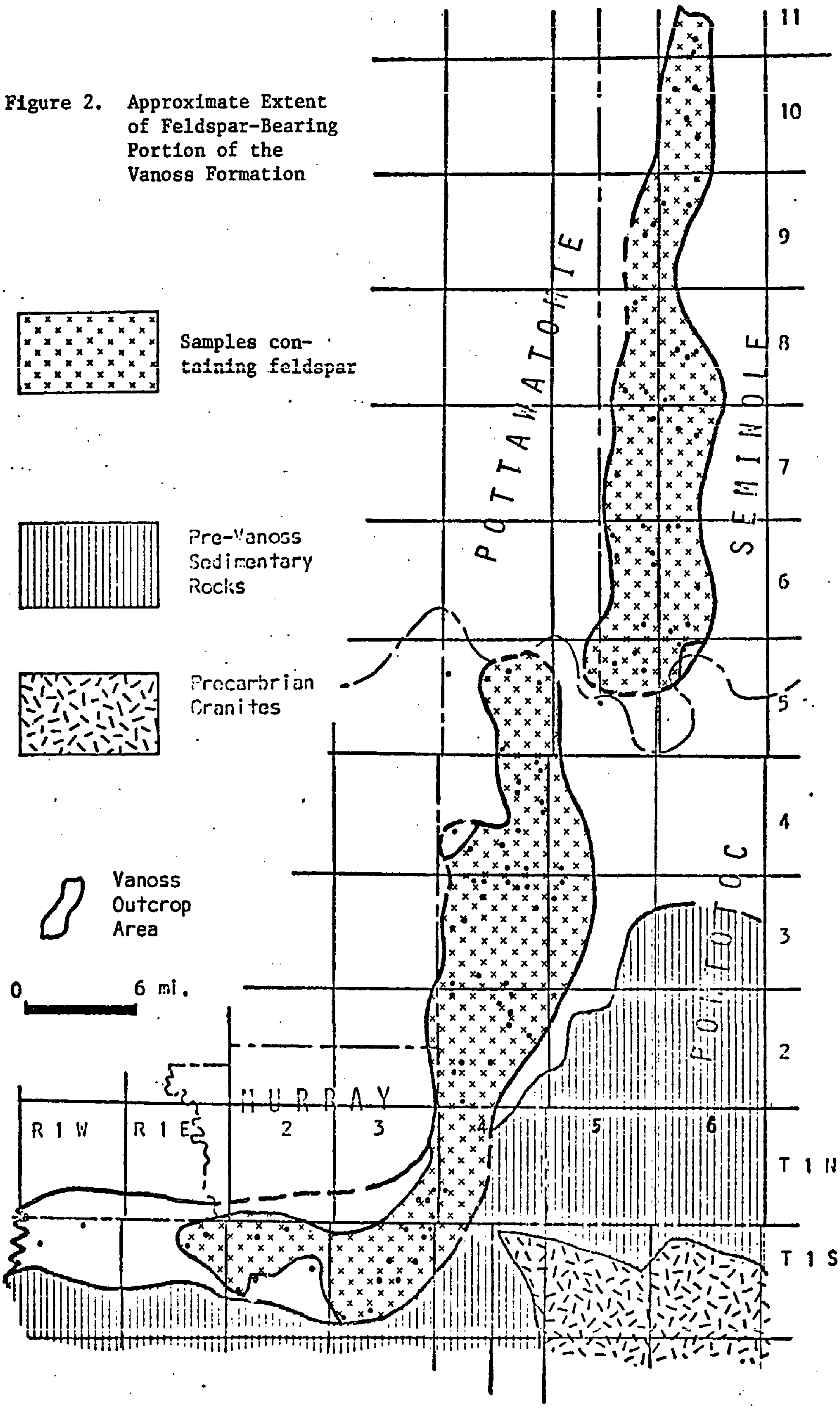
> North of Little River, the arkose line climbs in the section, and the contact between the two formations [Ada and overlying Vanoss], although drawn along what appears to be a continuous sandstone horizon, is still open to doubt. . . .

The generalizations Tanner makes about a rise in section of the arkosic portion of the Vanoss is only partially correct for two reasons. (1) In northern Seminole County thin-sections of samples collected stratigraphically below the obviously arkosic units in the Vanoss do contain sand-sized feldspar though in amounts far less than the coarser sands higher in the Vanoss Formation. (2) The rise in section he reports is generally at an angle to the true dip direction of the Vanoss (though the exact direction is unclear in Tanner's report). Therefore, based on field associations and thin-section studies, it is my interpretation that the lithology is different in the northern portion of Seminole County because the terrigenous clastics were being reworked by beach processes (as Tanner suggests) and that the base of the Vanoss is not horizontal but dips slightly to the west-northwest with local variations in apparent stratigraphic position and grain size due to alluvial fan deposition on an irregular erosional surface. Much additional field study to the west-northwest would be needed to verify this interpretation, however.

In an area of Pontotoc County (T. 3-4 N., R. 5 E.), Lowe (1968) mapped and described several exposures of Vanoss each of which reportedly contain no feldspar but megascopic kaolinite grains which probably are kaolinized detrital feldspar.

The most recent reference to the Vanoss is in Oklahoma Geological Survey Guidebook XVII (Ham, 1969) in which the author discussed the relationship of the Formation to Pennsylvanian tectonism in the Arbuckles and reiterated Morgan's observations about igneous detritus only being laid down in the final orogenic pulse. Thus, only the work by Ham and Dunham augments that of Morgan and the uplift geometry is still uncertain.

Figure 2. Approximate Extent of Feldspar-Bearing Portion of the Vanoss Formation



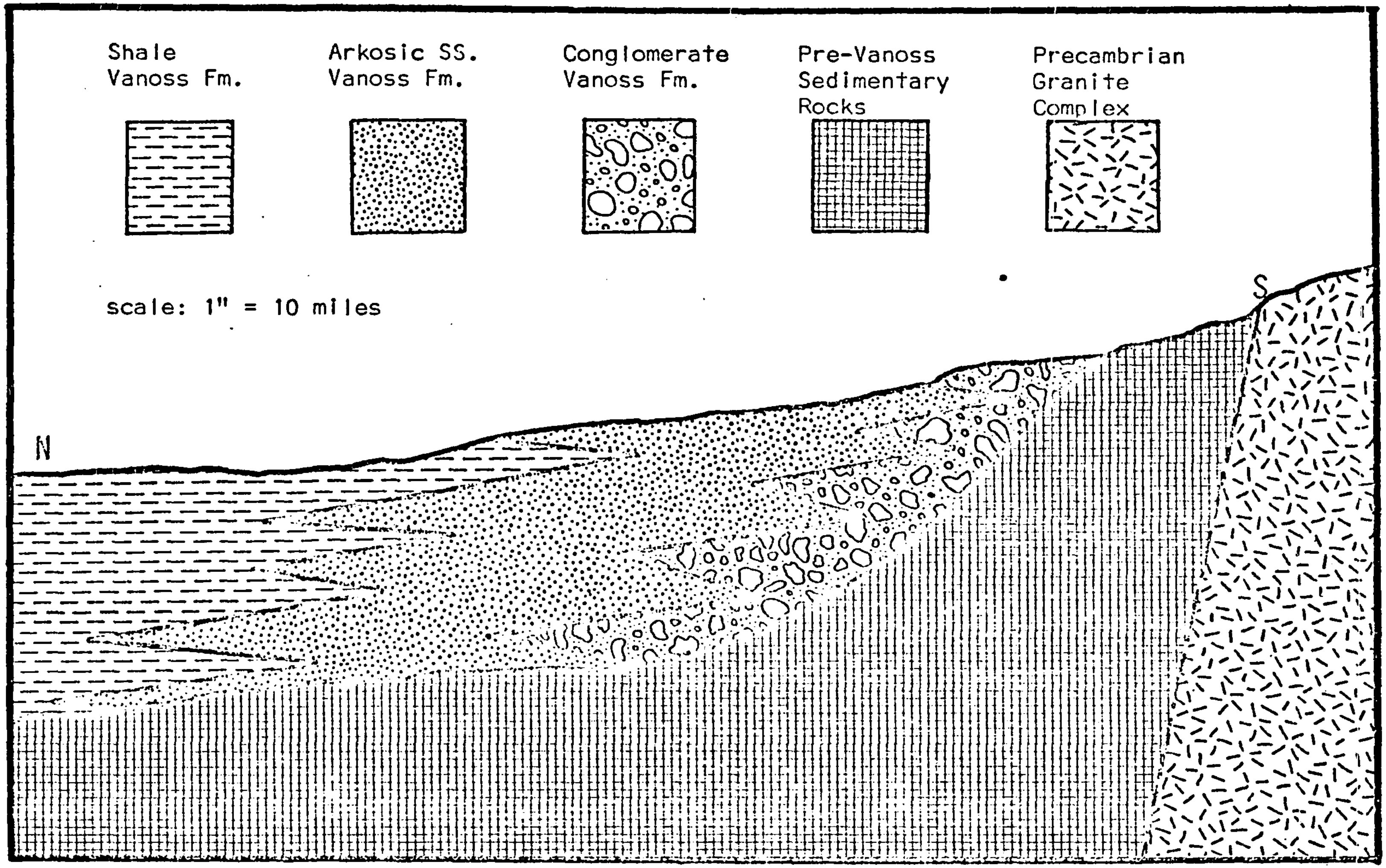
STRATIGRAPHY

The Vanoss Formation is Late Pennsylvanian and Early Permian in age within the type area (Morgan, 1924, p. 137) where it overlies the Pennsylvanian Ada Formation and underlies the basal Hart limestone member of the Permian Stratford Formation. Southward from there, however, the Vanoss overlies progressively older sedimentary rocks until it rests with sharp unconformity on rocks of Ordovician age in T. 1 S., R. 3 E. (see fig. 3). More than 350 square miles of Vanoss are exposed north of the Arbuckle Mountains.

The entire Paleozoic-Precambrian portion of the Arbuckle Mountains older than the Vanoss constitutes a source of Vanoss material. Only a discussion of the major sources of clastic detritus is included here and the reader is referred to Ham (1969) for a more detailed discussion of the Paleozoic stratigraphy of the Arbuckles.

Basement Rocks

The Arbuckle Mountains are floored by intrusive and extrusive igneous rocks. The "core" area is composed of a complex of two granites and associated diorite, diabase, simple pegmatites and aplite. This is called the Eastern Arbuckle Province by Ham, Denison and Merritt (1964) because it is exposed only in the eastern portion of the Arbuckles.



North-South Generalized Cross-Section Showing Major Lithofacies Within the Vanoss.

Figure 3

Several periods of plutonic injection are indicated by potassium-argon ages on surface and subsurface samples. Rubidium-strontium ages of the granites range between 1.2 and 1.38 billion years (Ham, Denison and Merritt, 1964, p. 127). These and similarities in mineralogy relate the Eastern Arbuckle Province to intrusive igneous rocks in the subsurface of adjoining areas of Texas.

Table 1 summarizes the mineralogy of selected outcrop samples from the Province (modified from Ham, Denison and Merritt, 1964, p. 132). Both the central Tishomingo and peripheral Troy granites (Taylor, 1915) are composed of microcline-perthite and plagioclase no more calcic than An_{13}, plus a simple heavy mineral suite. Higher percentages of biotite, magnetite, sphene, zircon, and andesine are present in diabase dikes cutting the granites and in the diorite "phase" of the Troy. Xenoliths are present in the granites and are of uncertain origin; perhaps they were derived from the country rock into which the mesozone granites were intruded (Ham, Denison and Merritt, 1964, p. 137).

The Tishomingo granite is readily separable from the Troy in hand specimen. It is pink to gray, coarse-grained and porphyritic, consisting of strained quartz grains about 3 millimeters in diameter, microcline-perthite crystals up to 50 millimeters long, albite, oligoclase, and accessory amounts of biotite, apatite, sphene and other minerals. The Tishomingo comprises about 60 per cent of the outcrop area.

TABLE 1

MODAL ANALYSES OF SELECTED IGNEOUS-OUTCROP SAMPLES
(JOHNSTON COUNTY, OKLAHOMA)

	Quartz	Micro-cline-per-thite	Plagio-clase	Bio-tite	Epi-dote	Horn-blende	Sphene	Opaq-ues	Zir-con	Apa-tite
Tishomingo granite Ten Acre Rock C NE 3-3S-5E	21.9	49.6	20.4 (An_{12})	2.1	1.1	. .	0.3	0.5	tr.	tr.
Troy granite (normal phase) Century Quarry SW SW 20-2S-5E	34.6	37.3	24.4 (An_{13})	2.0	tr.	. .	0.3	0.8	tr.	tr.
Troy granite (diorite phase) SE SW NW 32-2S-5E	13.4	. .	58.5 (An_{36})	8.4	0.3	15.5	0.4	1.3	0.1	0.1
Biotite-hornblende schist in diorite SE SW NW 32-2S-5E	16.4	. .	44.4 (An_{32})	8.2	2.6	21.6	2.4	3.6	0.1	0.1

Source: Ham, W. E.; Denison, R. E.; and Merritt, C. A. 1964. Basement rocks and structural evolution of southern Oklahoma. Okla. Geol. Survey Bull., No. 95. 302 pp.

<u>Troy</u> granite hand specimens are typically light gray, equigranular rocks consisting of equidimensional grains of quartz, microcline-perthite, and plagioclase 2 to 5 millimeters in diameter plus a larger percentage of accessory minerals (e.g., biotite, epidote, zircon, apatite and magnetite). (See Plate I.)

Considerably younger than the Precambrian "core" is the Colbert Rhyolite Porphyry. Considered part of the Wichita Province, its age is Middle Cambrian, based on an isotopic date of 525 million years (Ham, Denison and Merritt, 1964). The unit crops out over an area of less than 15 square miles in the East and West Timbered Hills (T. 2 S., R. 1 E. and T. 1 S., R. 1 W., respectively) near the western end of the Arbuckle Anticline (Ham and McKinley, 1954). Maximum thickness reported is 4,500 feet, thinning eastward onto the shelf area of the southern Oklahoma geosyncline (Ham, Denison and Merritt, 1964, p. 40).

The Colbert is generally a rhyolite porphyry exhibiting coarse flow-banding. Locally, columnar jointing, tuffs and volcanic breccias are observed. Albite, perthite and quartz phenocrysts are all commonly less than 5 millimeters in diameter. The aphanitic groundmass is composed of extremely fine-grained quartz, feldspar, chlorite and iron oxide "powder."

Alteration of feldspar in the Troy, Tishomingo and Colbert has produced crystals of kaolinite which have been interpreted to be of replacement rather than weathering origin because of the great thickness of altered rhyolite penetrated by the Shell #1 Galloway well, Sec. 21,

PLATE I

SELECTED VIEWS OF TROY AND TISHOMINGO GRANITES

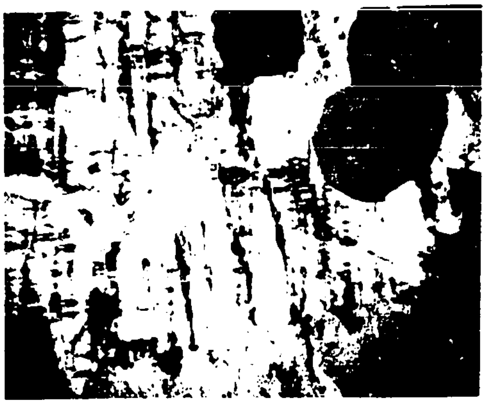
A. Complex intergrowth of Carlsbad-albite-twinned plagioclase crystal with strained quartz; Troy granite, Century Granite Quarry, SW 1/4, Sec. 20, T. 2 S., R. 5 E.; crossed nicols, 35 x.

B. Coarse microcline-perthite crystal enclosing subspherical monocrystalline quartz; Tishomingo granite, Ten Acre Rock, NE 1/4, Sec. 3, T. 3 S., R. 5 E.; crossed nicols, 35 x.

C. Typical exposure of porphyritic Tishomingo granite; Ten Acre Rock; length of pen is six inches.

D. Characteristic appearance of weathered grus developed on Troy granite; S 1/2, Sec. 2, T. 2 S., R. 5 E.; length of rule is twelve inches.

A.



B.

C.

D.

T. 8 N., R. 18 W. (Ham, Denison and Merritt, 1964, p. 58). In addition, the writer has observed subhedral crystals of epidote and pyrite of replacement origin in the rhyolite and granite basement rocks.

Paleozoic Source Rocks

The basal unit of the Paleozoic sedimentary rock section, and of the Timbered Hills Group, is the Upper Cambrian (middle Croixian) Reagan Formation (see fig. 4) which is overlain by the slightly quartzose Honey Creek Limestone. The Reagan is a coarse to medium grained, poorly sorted, subangular, locally glauconitic, iron oxide-rich, silica-cemented sandstone which is feldspathic at its base. The pink feldspar clasts undoubtedly were derived from the Precambrian and/or Middle Cambrian basement rocks. Thicknesses are highly variable (0 to 450 feet) and probably are due to nondeposition around basement topographic "highs" and to post-depositional erosion (Ham, 1969, p. 8).

Conformable upon the Timbered Hills Group lies the Arbuckle Group, a stratigraphic sequence composed of marine dolomites and limestones. These rocks contain almost no sand-size silicate detritus.

Unconformable upon the Arbuckle Group rests the Simpson Group of Middle Ordovician age. This sequence consists of more than 6,000 feet of sedimentary rocks divided into five formations, each having a basal sandstone, middle gray-green shale and upper limestone member. In ascending order the formations are the Joins, Oil Creek, McLish, Tulip Creek and Bromide. The basal sandstones are composed of rounded, well-sorted, frosted quartz grains 1 Ø to 2 Ø in size. The writer has not observed a well-developed basal sandstone unit in the Joins

PERIOD	GROUP FORMATION
	Vanoss Conglomerate
PENNSYLVANIAN	Ada and Collings Ranch Conglomerates
	"Franks" and Deese Conglomerates
	Goddard Shale
MISSISSIPPIAN	Caney Shale (Delaware Creek)
	Sycamore Limestone
DEVONIAN-SILURIAN	Woodford
	Hunton Limestone
	Sylvan Shale
	Viola Limestone
	Simpson Group
	Bromide Dense (Pooleville)
	Mountain Lake
	Tulip Creek Sandstone
ORDOVICIAN	McLish Limestone
	Basal McLish Sandstone
	Oil Creek Limestone
	Basal Oil Creek Sandstone
	Joins
	Arbuckle Limestone
	West Spring Creek
	Kindblade
	Cool Creek
	McKenzie Hill
	Butterly Dolomite
	Signal Mountain
	Royer Dolomite
	Fort Sill
CAMBRIAN	Timbered Hills Group
	Honey Creek Limestone
	Reagan Sandstone
	Colbert Rhyolite Porphyry

Figure 4

GENERALIZED GEOLOGIC SECTION, NORTHERN
FLANK ARBUCKLE MOUNTAINS

Formation exposed in the Arbuckle Mountains. Because of the conspicuous character of the Simpson Group grains, their presence in the Vanoss is easily recognized. More than 95 per cent of the quartz grains exhibiting overgrowths in the Vanoss are typical Simpson spheroids.

Total thickness of the Simpson Group in the Arbuckle Anticline is about 2,300 feet (Ham, 1969, p. 10). The thickest basal sandstone member is that of the Oil Creek Formation which is approximately 350 feet thick (Ham, 1969, p. 47).

Following deposition of the Simpson Group, an extensive thickness of marine carbonates and shales was deposited (Ordovician through Mississippian time). In order of deposition they are, Viola Limestone, Sylvan Shale, Hunton Group carbonates, Woodford shale and chert, Sycamore Limestone, Caney Shale and Springer Group shale.

Average thickness for the entire sequence of rocks as they occur in the Arbuckle Anticline is in excess of 12,000 feet (Ham, personal communication) with the Arbuckle Group making up about one-half to three-quarters of the sequence (varying depending on erosion). The Pre-Pennsylvanian sedimentary rocks can supply fragments of shale, carbonate, chert and spheroids of sand-size quartz to the Vanoss sediments.

Deposition in the Pennsylvanian Period began as a marine sequence and terminated with alluvial fan, terrestrial deposits. In the immediate area of investigation, the predominantly marine Morrowan, Atokan and lower Desmoinesian Series may have been deposited but are not represented because of erosion and/or nondeposition.

Beginning with deposition of the "Franks" and Deese

Conglomerates during Desmoinesian time, the northern flank of the Arbuckle Mountains was periodically blanketed by terrigenous clastics. Ham (personal communication) has also applied the term Deese to the few thin conglomerate lenses of Missourian age found in the Arbuckle Mountains.

Three Virgilian conglomerates are present in and close to the Arbuckle Anticline; the Collings Ranch Conglomerate, Ada Formation, and Vanoss Conglomerate. An estimated 3,000 feet thick (Fay, 1969, p.75), the Collings Ranch is a spar-cemented limestone boulder-cobble conglomerate largely restricted to a northwest-trending graben in portions of T. 1 S., and R. 1-2 E. The oldest clasts reported from the Collings Ranch Conglomerate are of upper and middle Arbuckle Group origin while Precambrian boulders are in the Vanoss. The lithologic contrast between the carbonate boulders in the Collings Ranch and the granite boulders in the Vanoss plus the observation that faults cutting the Collings Ranch do not cut through the Vanoss, led Dunham (1955, pp. 27-30) to conclude that the Vanoss is younger than the Collings Ranch.

The Ada Formation (Morgan, 1924, p. 128) is a spar-cemented limestone cobble conglomerate which crops out around the Lawrence Uplift of the Arbuckle Mountains (T. 2 and 3 N., R. 5 E.). To the north in Seminole County, the upper portion grades into multicolored shales and well-cemented sandstone. It is unconformably overlain by the Vanoss Formation north of the T. 3 N. area to T. 11 N., but to the south of the Uplift, it is not exposed, probably because of covering by Vanoss sediments and nondeposition. Ham (1954) felt that the Ada is contemporaneous with the Collings Ranch and that its maximum thickness of about 100 feet was due to less tectonic activity in the area of the Lawrence Uplift while the Arbuckle Anticline was being rapidly uplifted.

At the Canadian River, about 60 miles north of the present mountain front, the Ada becomes lithologically gradational into the Vanoss and is mapped with the Vanoss (Miser, 1954).

The Vanoss Formation, as originally defined by Morgan (1924, p. 133), is made up of shales, sandstones, conglomerates and limestone, all of which are arkosic. Conglomerate and shale present in the Lake Classen area (Dunham, 1955, p. 15) and around Sulphur (T. 1 S., and T. 1 N., R. 3 E.) generally contain no feldspar. However, Morgan recognized the conglomerates at Sulphur were definitely younger than the "Franks" and Seminole Conglomerates and did not preclude correlation into the Vanoss of the type locality (1924, p. 122).

Within the Stonewall Quadrangle, Morgan (1924, p. 134) reported Vanoss thicknesses between 250 and 650 feet, while Dunham (1955, p. 16) estimated a thickness of 500 feet in the Lake CLassen area. Ham (1969, p. 18) suggested a maximum thickness of 1,550 feet along the north flank of the Arbuckle Mountains. From the writer's experience, the latter value must be considered a maximum reconstructed thickness; the thickest section the writer measured was only 30 feet.

Morgan drew the contact between the Ada and Vanoss Formations on the surface above which the strata were arkosic. Referring to the Stonewall Quadrangle, he stated (1924, p. 134):

> Due to the lenticular nature of the strata along the contact and the fact that the Vanoss is progressively overlapping southward, no one stratum can be selected to mark the adjacent limits of the formation. The base of the arkosic zone, however, is relatively contemporaneous.

This statement contrasts with that made by Tanner (see p. 6) because Morgan did not recognize any time-transgressive character in the Vanoss exposed in the Stonewall Quadrangle.

In slight angular unconformity overlying the Vanoss, north from the Lawrence Uplift area, is the Stratford Formation (Morgan, 1924, p. 137). Within the Stonewall Quadrangle the contact is clearly defined by the basal Hart limestone member of the Stratford. The Hart consists of a series of seven or more thin limestone beds, locally feldspathic but typically a light gray, argillaceous, slightly recrystallized, slightly fossiliferous micrite. Southward from the abandoned Hart post office, Sec. 19, T. 3 N., R. 4 E., the beds grade into shale.

Age of the Vanoss

The age of the Vanoss is based on sparse faunal evidence, collected by Morgan (1924) and Tanner (1956), and stratigraphic relationships with more fossilifeous strata to the north and south. Morgan found plant fossils of definite late Pennsylvanian age (e.g., *Neuropteris ovata*, *Pecopteris hemitelioides* and *Cordaites sp*.) in shales in two localities; Sec. 32, T. 5 N., R. 5 E. and Sec. 19, T. 4 N, R. 5 E. Both Morgan and Tanner collected poorly preserved specimens of the gastropod *Bulimorpha inornata* (?). A single limestone bed which crops out in several places in T. 4 N., R. 5 E. and T. 5 N., R. 5 E., yielded a molluscan assemblage of upper Pennsylvanian--lower Permian age (e.g., *Belerophon bellus*, *Myalina recurvirostrus* and *Naticopsis altonensis*).

In what is apparently a deltaic sequence of cross-bedded sandstones in the Vanoss (Sec. 31, T. 8 N., R. 6 E.), poorly preserved plant fragments were collected by the writer and identified by L. R. Wilson (1971, personal communication) as fragments of *Calamites* and perhaps Cordaites of upper Virgilian--early Wolfcampian affinity. In the same sequence, a few tiny, heavily abraded bryozoan and molluscan fragments were found, which compare favorably with the bryozoan, Rhombopora and pelecypod, Edmondia reported by Tanner (1956, p. 108).

More fossiliferous limestones stratigraphically higher and lower than the Vanoss help establish that the approximate age is upper Virgilian--lower Wolfcampian. Fay (1971) identifies the Reading Limestone (upper Pennsylvanian) as the approximate equivalent of the base of the Vanoss by lithologic correlation from the Reading of Kansas southward into central Oklahoma. Since the coarse clastic portion (and associated detrital shales) of the Vanoss is not identifiable as a mappable unit separate from the Ada Fromation north of T. 11 N., correlation from Kansas of a thin bed such as the Reading must be considered tenuous.

Tectonic Setting

An excellent discussion relating the Vanoss Formation to other conglomerates and to the orogenic development of the Arbuckle Mountains is offered by Dunham (1955). Accumulation of the Virgilian conglomerates represents the final deformation of the Arbuckles (i.e., the Arbuckle Orogeny).

Beginning in the Desmoinesian, uplift and folding of the lower Paleozoic strata of the Arbuckle Mountains took place. Associated erosion produced alluvial fan deposits composed chiefly of Arbuckle Group (Cambro-Ordovician), Hunton Group (Siluro-Devonian) and Simpson Group (Ordovician) clasts. Following a period of apparent quiescence, the Arbuckle Anticline (and Lawrence Uplift) were uplifted in Lower Virgilian time. Clastic wedges composed of Upper Cambrian (?) and younger detritus formed the Collings Ranch and Ada Formation conglomerates. Faulting and folding with a north-northwest strike occurred after deposition of the above conglomerates.

Late in Virgilian time, a final orogenic pulsation occurred in the Arbuckle Mountains and produced another wedge of sediments, the Vanoss. Initially only rocks younger than Middle Cambrian were eroded but soon the Precambrian basement was unroofed. The final wedge blanketed older strata and was only slightly deformed after deposition.

Rates of uplift and thickness of sedimentary cover in the Arbuckle Anticline probably were greater than in the Lawrence Uplift, which is on the shelf of the southern Oklahoma geosyncline. Therefore, the onset of erosion of basement rocks was not isochronous in the two areas. For this reason, the writer feels that granitic debris might have accumulated locally in the Ada or Collings Ranch Conglomerates. Tanner reported two instances of arkose in strata he considered to be Ada (1956, p. 102) and Sutherland (1971, personal communication) collected a Troy granite pebble from the Ada Formation in Sec. 5, T. 3 N., R. 6 E.

METHODS OF INVESTIGATION

Field Studies

Samples for analysis were collected during 1969 and 1970. Seventeen samples were initially collected in 1969 for preliminary evaluation of the problem and the remainder were collected in 1970. Each of the 147 sample collection sites is shown on the map (Plate V) and each locality is keyed to a description in Appendix D. Field mapping and the selection of sample sites was done using aerial photographs provided by the Oklahoma Geological Survey, 7.5-minute topographic maps and county highway maps of the area. For general information, the writer referred to the Regional Geology Map of the Arbuckle Mountains (Ham, 1969) and the state Geologic Map (Miser, 1954).

Samples were collected in traverses approximately normal to the strike of the Vanoss Formation. Material was collected from every section in each township where possible granitic detritus could be expected or had been noted in first sampling. This eliminated from evaluation the coarse limestone-cobble conglomerate which does not contain granite-derived detritus and is exposed at the extreme southern limit of the Vanoss outcrop area in Murray County. Thus, samples were of limestone-pebble conglomerate (18), sandstones (128) and shales (10) expected to contain granitic detritus. Each sample consisted of about

1,000 grams of material obtained from the freshest portion of the outcrop by means of trenching. More friable or argillaceous outcrops required extensive trenching. When present, shale associated with lenses of coarser clastic material was sampled so that the mineral composition of the sand fraction of shales and sandstones could be compared.

The location, elevation, vertical position of the sample and field rock description were recorded for each sample. Elevations were determined by means of hand level, Jacob's staff and steel tape from elevations listed on the topographic or county maps.

Thin-Section Analysis

Of the 147 samples, 137 coarse clastic samples (both silicate and carbonate were selected for thin-sectioning; friable samples were impregnated with an isotropic resin for slide preparation. No thin-sections were made of the coarse limestone-cobble conglomerate that lacked igneous-derived clasts. Each slide was assigned a randomly chosen four-digit number and the master list relating number to sample locality was kept by Dr. Harvey Blatt to reduce possible human bias in analysis. Wherever possible, the thin-sections were cut normal to apparent bedding or lamination.

Each slide studied was evaluated for mineralogy, grain size and roundness by means of a fixed-distance linear traverse until either the minimum number of points or the entire slide had been covered.

Mineralogy was determined from 300 points and observations tabulated in one of the categories following (raw data shown in

Appendices A and B):

Quartz: Monocrystalline; nonundulatory, undulatory
Polycrystalline
(Numbers of grains exhibiting overgrowths, vein origin and the number of crystals in polycrystalline grains also)

Feldspar: Twinned Plagioclase
Microcline
Orthoclase
Perthite
Untwinned feldspar of uncertain identity
(Abundances of twin-types were also noted; microcline, albite, pericline, Carlsbad and "others")

Rock Fragments: Granite Rock Fragments
Metamorphic Rock Fragments
Sedimentary Rock Fragments; including sandstone, limestone, shale, dolostone and chert

Other Minerals: Biotite
Muscovite
Clay minerals; Kaolinite, Illite and Montmorillonite (sericite for indeterminable clays)
Chlorite
Unknowns

Heavy Minerals: Magnetite

Hematite

Rutile

Hornblende

Tourmaline

Epidote

Garnet

Others

Cementing Agents: Calcite; micrite, spar

Dolomite

Silica

Siderite

Clay Minerals

Alterations Observed: Feldspar to clay, calcite

Dolomitization

Recrystallization of calcite

Silica

"Chertification"

In addition, 100 quartz, feldspar and granite rock fragment grains were studied for their size by micrometer ocular and for roundness. The Folk modification of Power's Roundness Scale (1955, in Folk, 1968) was used.

Each slide was then assigned two clan names based on the triangular classification of McBride (1963). Using Feldspar, Quartz and Chert, and Rock Fragments as McBride does, the initial clan name is determined. The second name arose by considering only Granite Rock Fragments, Feldspar and Quartz (excluding chert and overgrown grains) as poles, corrected to 100 per cent. The writer used these three poles because they represent the chief constituents of the Vanoss which were derived from a plutonic igneous source, of primary importance in identifying igneous and sedimentary source rock contributions. In addition, composition of a thin-section within such a scheme suggests the relative relationship between mineralogic maturity and distance from the common source; quartz more durable than feldspar which is more durable than granite rock fragments. Using either categorization, however, takes reworking or recycling into consideration better than other published classification schemes.

Clay Mineral Analysis

Though the presence of clay minerals in the samples was recognizable optically, identification of clay minerals groups (i.e., Kandite, Illite and Smectite) was unreliable due to frequent iron oxide pigmentation of fine-grained matrix and authigenic materials. The types and relative abundances of clay minerals were determined by X-ray diffraction methods. Oriented and unoriented slides were prepared and analyzed on a Norelco diffractometer using Cu K-alpha radiation and scanning all samples over the interval 2 through 45 degrees 2 θ at a rate of 1 degree 2 θ per minute. All samples were initially analyzed using oriented slides; those which gave inconclusive results were then studied by random-oriented (Vaseline), glycolated, or heated (oriented) slides. Three samples were also analyzed by a Jelco Scanning Electron Microscope.

Sample preparation for X-ray analysis followed the procedure below (raw data shown in Appendix C):

1. Select approximately 20 grams from opposite quarters of disaggregated, coned sample.
2. Lightly grind sample in agate mortar until portion passes through a 230 Mesh sieve.
3. Mix the separate (silt and clay fractions) into distilled water and allow to settle for at least 12 hours. Retain remainder for further evaluation if needed.
4. Add acetone to those samples which do not settle out in 12 hours (contain hydrocarbons).
5. Mix vigorously for 60 seconds, let settle for 15 seconds, draw off sample from upper one-half centimeter and drip onto glass slide; ideally all particles are less than 10 microns in size.
6. Evaporate at 50 degrees C for not less than 12 hours.
7. Random orientation slides--deposit layer of less than 10 micron fractions onto slide coated with petroleum jelly; retain in drying jar.
8. Heated slides--place oriented slide in oven at 550 degrees C for not less than 2 hours.
9. SEM samples--coat hand-picked grains with Gold-Platinum alloy in vacuum jar.

In addition to the above samples, several bulk powder slides were prepared from material ground to less than the 120 mesh size for the purpose of better definition of the cementing agents present.

Relative Abundances of Clay Minerals

A measure of the relative abundances of the clay minerals identified in each sample was desired for the purpose of investigating the possible existence of changes due to diagenesis of the clay suite of sandstones and shales of the Vanoss Formation. The maximum amplitude of the lowest-order basal reflection of each clay group was multiplied by the peak width at one-half peak height, somewhat analogous to determining the area of a triangle. Comparisons are between the (001) peaks of kaolinite and montmorillonite and the (002) peak of illite. The writer determined the ratio of peaks for illite: montmorillonite: kaolinite to be about 1/3 : 1/3 : 1 by making a mechanical mixture of equal weights of Georgia kaolin, Fithian illite and a Wyoming bentonite (API standards). Five sedimented slides were prepared and yielded nearly identical diffraction patterns. As with patterns made of Vanoss samples, the scale factor was constant (500).

Factors limiting the quantitative value of the intensity ratios are numerous. Presence of mixed-layer clay in some samples tends to smear out peaks and thus, the true ratio of illite and montmorillonite to kaolinite is only approximated. In such cases, the slides were run after heating at 125°C for at least 5 hours. Varying degrees of crystallinity of illite, montmorillonite and kaolinite tend to make peaks irregular or, in the case of kaolinite, too narrow, making the area under the peak a poor approximation of abundance. In some slides the second-order "kaolinite" peak is more intense than the first, suggesting the presence of dickite rather than kaolinite; this could not be supported by powder-pack X-ray slides except for one sample (number 19).

Heavy Mineral Analysis

The presence of carbonate cement and rock fragments required that the samples be treated in acid. Of the original sample which had been gently disaggregated, opposite quarters of a cone of material were separated and treated. For clastic limestones, initial samples were at least 40 grams in weight while only 20 grams of detrital silicate sample were used. The procedure used was as follows:

1. Place dry sample in beaker and add 20 per cent HCl as often as needed until digestion is complete.
2. Boil briefly in 20 per cent HCl to remove most iron-staining.
3. Wash residue with distilled water until satisfactorily free of HCl.
4. Evaporate to dryness in oven at 80°C.
5. Place 10 gram split of dried residue in 100 ml. centrifuge tube and add 30 to 40 ml. tetrabromoethane; density is 2.825.
6. Allow separation for at least 12 hours, stirring periodically to ensure good separation.
7. Freeze heavy mineral extract in dry ice; wash off light mineral fraction with acetone.
8. Wash heavy mineral button into filter paper with acetone; wash three more times with acetone.
9. Weigh air-dried filter paper plus contents after 72 hours; remove heavies and reweigh.

10. Mount extracted minerals in piperine (n = 1.68).
11. Point count by linear-traverse. Minimum number points is 100 or total number of heavies encountered on slide.
12. Record mineralogy, grain size, grain form (anhedral, subhedral or euhedral) and percentages of opaque and nonopaque heavy minerals.

Much experimentation was carried out before deciding on the procedure outlined. Thin-section study showed many of the samples to be low in nonopaque heavy mineral content. Of the 147 heavy mineral separations made, seven yielded no heavy minerals and forty-four contained less than 100 grains. The large number of slides containing such low percentages of heavy minerals is attributed to extensive removal by solution of heavies during diagenesis. Also, since most heavy minerals were opaques, they were not separated from nonopaques in order that a good estimate might be made of the opaque to nonopaque ratio.

Sieve Analysis

Size determinations of grains were not accomplished by sieving because of the presence of a large, varying percentage of carbonate rock fragments as well as the common carbonate cement. Three samples were initially sieved but the high number of broken carbonate clasts (never less than 20 per cent of the carbonate grains originally present) was felt to be too great for acceptance. Grain size determinations were, therefore, made from thin-section observation and may be corrected to mechanical separation values by applying the correction factors of Friedman (1958). Had a size distribution of the noncarbonate portion of the clastic makeup of the Vanoss been desired, mechanical sieving would have been desirable.

THIN-SECTION ANALYSIS

The distribution of minerals and varieties of minerals shows variation related to changes in textural and mineralogic maturity as well as to the location of source areas during formation of the Vanoss. Table 2 categorizes all thin-sections of clastic rocks analyzed from the Vanoss Formation according to the system of McBride (1963). Column (a) groups according to McBride's parameters and column (b) classifies the thin-sections according to the modified poles mentioned previously (see p. 26). Distribution of the analyses is shown in Figures 5 and 6. The average Vanoss clastic rock north of the region of limestone cobble conglomerate is a lithic subarkose according to either classification scheme. According to the poles chosen by McBride, the rock contains 66.1 per cent quartz, 16.8 per cent feldspar and 17.1 per cent rock fragments. Considering igneous-derived detritus, the rock is relatively enriched in quartz and feldspar because of the high percentage of sedimentary rock fragments (limestones) eliminated; 68.8 per cent quartz, 20.5 per cent feldspar and 10.8 per cent rock fragments.

Ideally, mineralogic maturity of a sandstone should increase as distance from a point source increases (Folk, 1968). North of the Arbuckle Mountains the Vanoss should become relatively enriched in

TABLE 2

SUMMARY OF VANOSS FORMATION SANDSTONE TYPES BY THIN-SECTION ANALYSIS

Lithotype	(a) No. (%)	(b) No. (%)
Quartz sandstone	5(3.8)	8(6.3)
Subarkose	45(34.6)	57(44.9)
Sublithic sandstone	8(6.2)	1(0.8)
Lithic subarkose	5(3.8)	10(7.8)
Arkose	3(2.3)	17(13.4)
Lithic arkose	32(24.6)	29(22.8)
Feldspathic lithic sandstone	19(14.6)	5(3.9)
Lithic sandstone	13(10.0)	0(0.0)
Totals[a]	130(99.9)	127(99.9)

[a]18 conglomerates, 3 without granite rock fragments; 137 total samples including--5 limestones, 1 poor slide, 1 sample of igneous grus.

quartz away from the mountain front. In the Vanoss such variation is not clearly evident though Ham (1969) implied that the Arbuckle Mountains represented a simple point source for Vanoss detritus. The trend of diminishing grain size and abundance of carbonate rock fragments northward from the source area as seen in T. 1-2 S. is countered by increasing grain sizes of igneous detritus northward into T. 4 N. indicating more than one source area for Vanoss material. The following distribution data will indicate the change in the two mineral

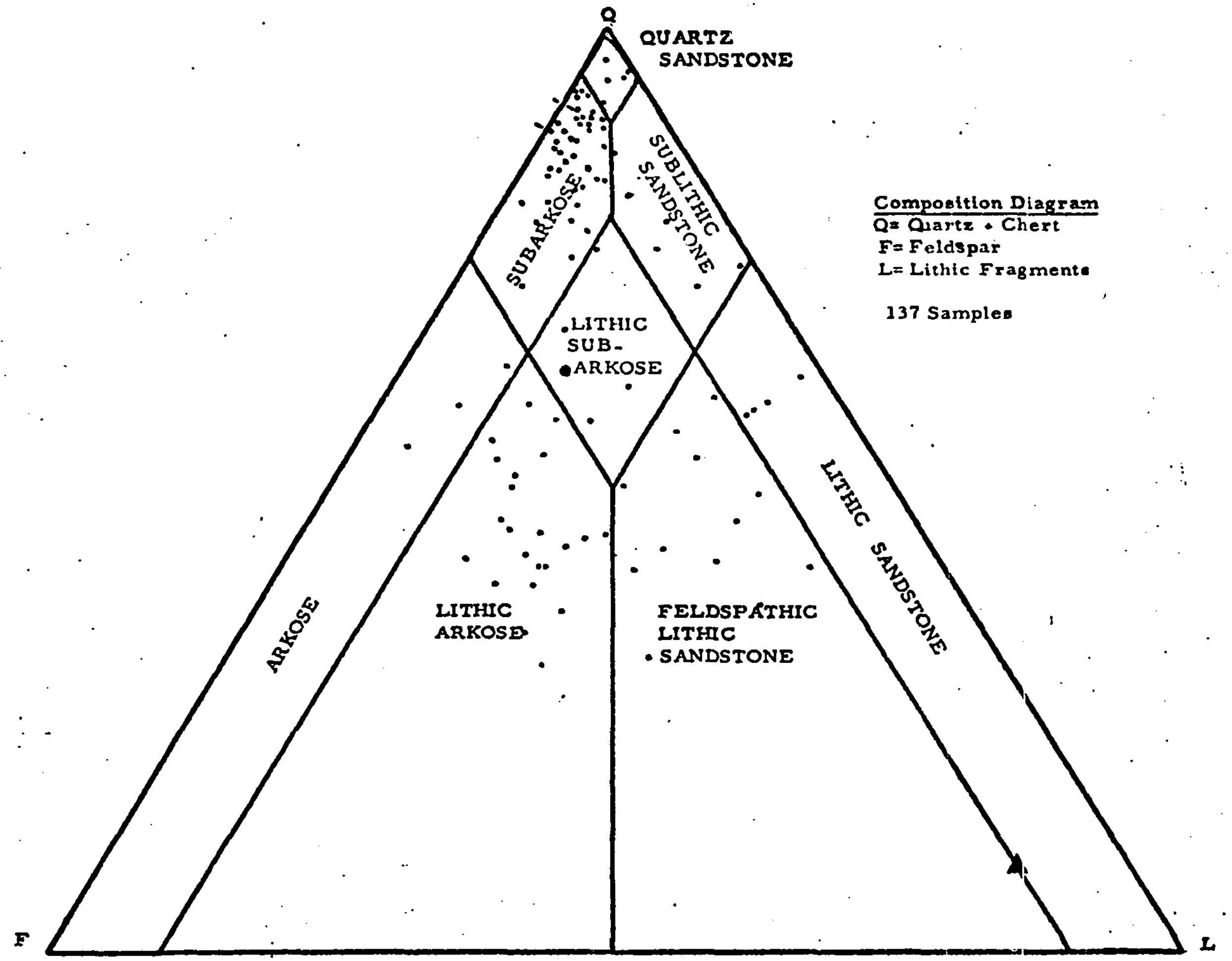


Figure 5. Triangular Composition Diagram after McBride (1963); Triangle in lower right represents plot of granite grus and large dot in Lithic Subarkose field is average composition of all samples.

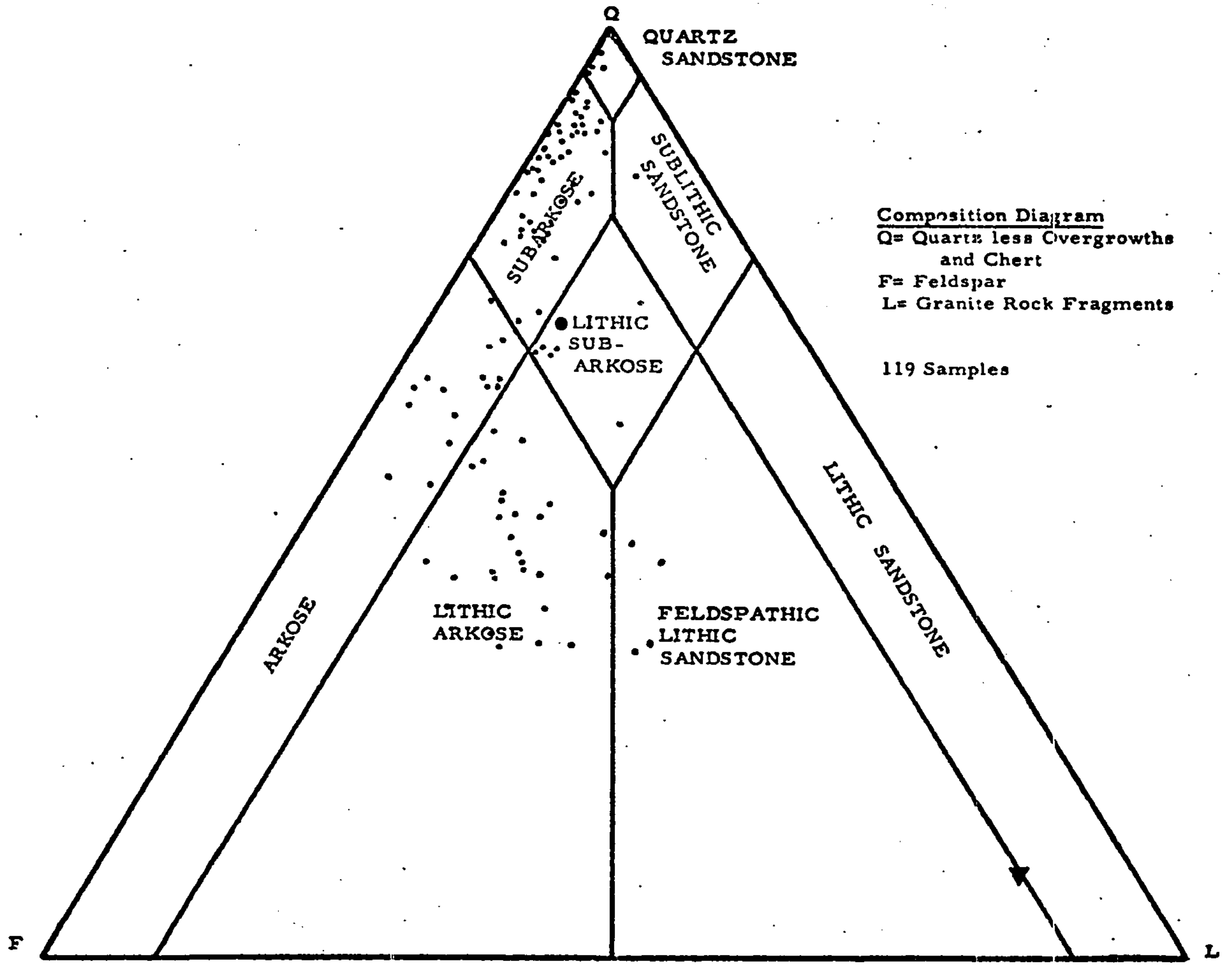


Figure 6. Modified Triangular Composition Diagram; Triangle in lower right represents plot of granite grus and large dot in Lithic Subarkose field is average composition of all samples.

associations in the Vanoss.

Quartz

The occurrence of the several varieties of quartz in the Vanoss may be divided into three geographic zones: (1) from T. 2 S. to T. 1 N. where Simpson-derived spheroids are most abundant; (2) a middle region (T. 2 N. to T. 6 N.) where admixtures of polycrystalline and non-overgrown monocrystalline quartz grains are most common; and (3) the northern zone (T. 6 N. to T. 11 N.) where nonovergrown monocrystalline quartz predominates.

The following concentrations of quartz varieties were obtained based on the 37,369 quartz grains counted: monocrystalline nonundulatory, 65.1 per cent; monocrystalline undulatory, 29.4 per cent; and polycrystalline quartz, 5.0 per cent. Sizes of quartz grains ranged from 0.2 Ø to 3.7 Ø with a mean of 2.1 Ø and standard deviation of 1.1 Ø. Average roundness for these grains was 2.2 (subangular) with individual grains varying between 1.5 and 3.5 according to Folk's scale (1968, p. 1). Grains in the size range 1.0 Ø to 2.5 Ø were the most round since that is the size of the overgrown quartz spheroids derived from the Ordovician Simpson sandstones. Overall grain size variation of quartz is shown in Figure 7.

Only 9.8 per cent of the quartz grains in the thin-sections were overgrown with secondary silica, although overgrowths appeared in 78 per cent of the thin-sections. Less than 1 per cent of these grains showed subhedral or euhedral overgrowth outlines and those were randomly scattered in the limestone conglomerates of T. 1 S. and T. 1 N. No

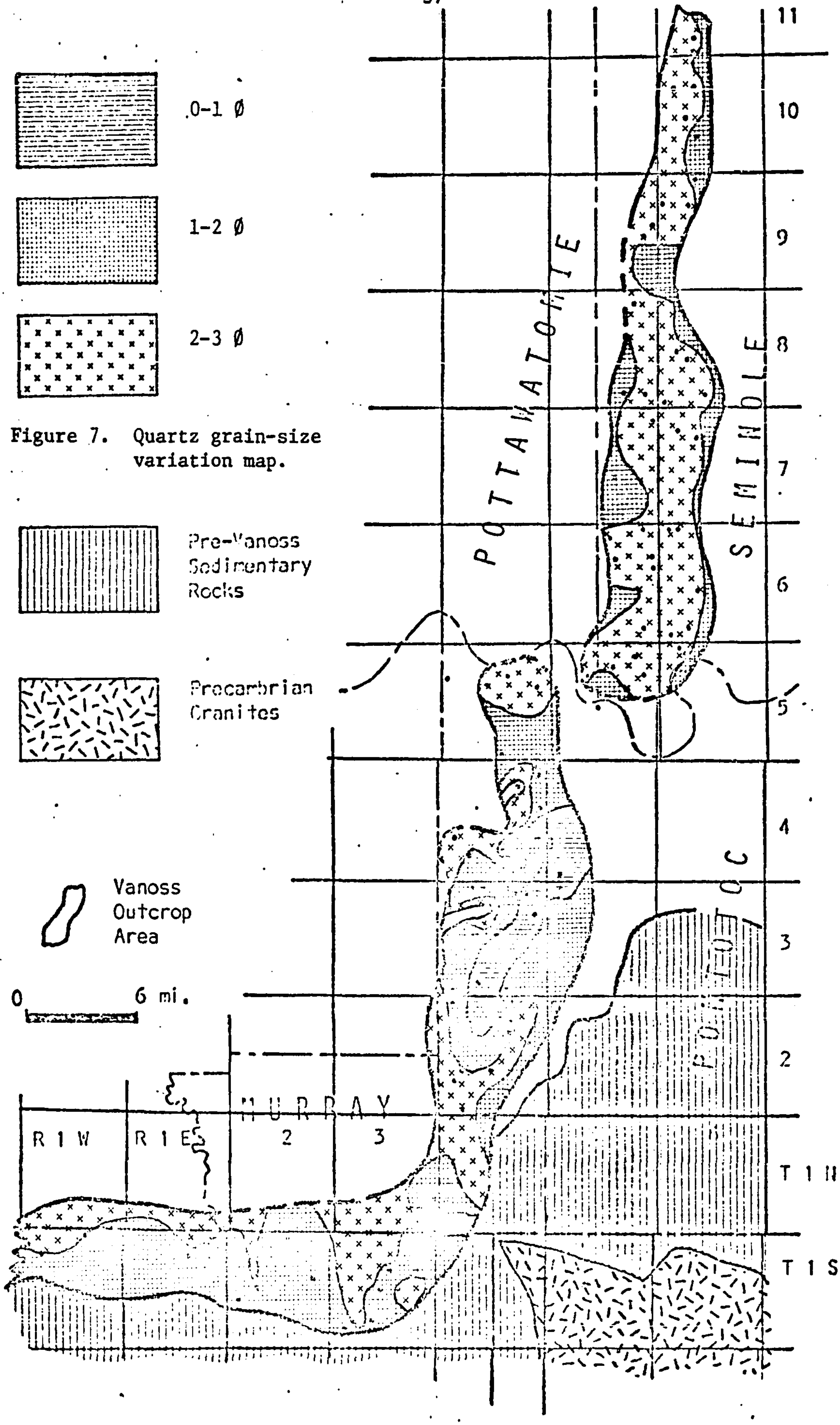


Figure 7. Quartz grain-size variation map.

polycrystalline quartz grain had an overgrowth. Each of the several varieties are discussed separately with respect to abundance and areal distribution.

Both monocrystalline varieties of quartz (nonundulatory and undulatory) in the Vanoss are common throughout the entire outcrop area but predominate in the northern and southern zones as mentioned earlier. Overgrown monocrystalline quartz grains typically were clear; undulatory grains showed abundant bubble trains, fracturing, chlorite "worms" and rutile-like inclusions (see Plate II). In studies in which the crystalline source rocks are unknown, little source rock information can be obtained from a study of monocrystalline varieties of quartz (Blatt and Christie, 1963, p. 574). In this study, however, the vermicular chlorite and rutile inclusions are present in the Troy and Tishomingo granites. The degree of undulatory extinction of monocrystalline undulatory quartz is of no value. Blatt (1967a, p. 409) and others have shown that this optical property, measured on a flat-stage petrographic microscope, differs markedly from the same measurements made on a universal stage and, therefore, offers little genetic information for sandstone petrology. Distribution maps of undulatory and nonundulatory quartz in the Vanoss Formation show only random concentrations and are not included.

Polycrystalline quartz, however, has been shown by Blatt (1967a, p. 411-415) to be useful for provenance determinations. In the Vanoss samples, 89.1 per cent of the sand-sized polycrystalline quartz grains were composed of less than five crystals. This compares well with Blatt's work (see fig. 8) in which 87.2 per cent of the

PLATE II

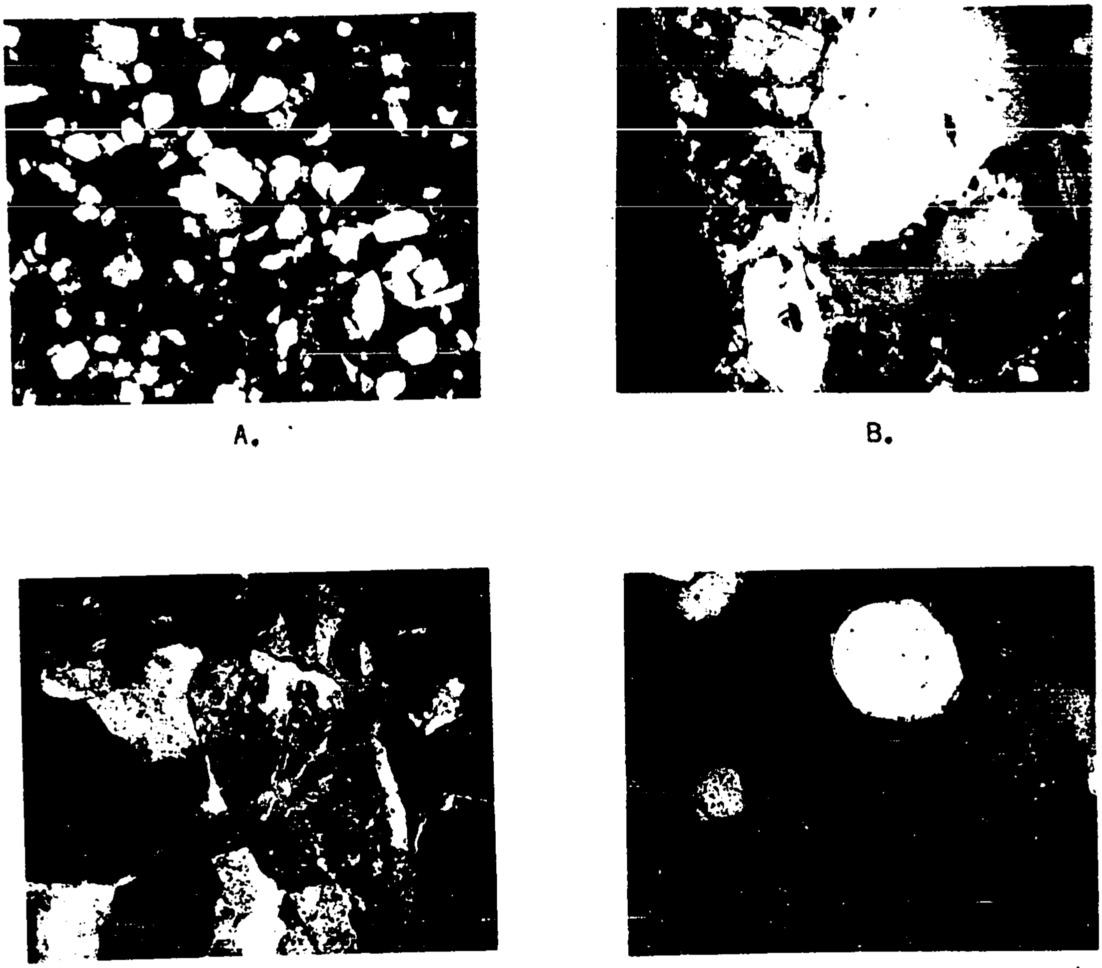
SELECTED VANOSS THIN-SECTIONS

A. Subrounded monocrystalline quartz and subangular plagioclase cemented by iron-stained kaolinite in most northerly sample; Thin-section 4029, SW 1/4, Sec. 33, T. 11 N., R. 6 E.; crossed nicols, 35x.

B. Fresh, sutured quartz grain surrounded by iron-stained calcite cement, angular quartz and rounded limestone rock fragment near presumed igneous source; Thin-section 8299, SE 1/4, Sec. 2, 1 S., R. IE.

C. Rounded granite rock fragment in coarse spar cement. Note also altered perthite grain and speckled (clay altered) orthoclase grain; Thin-section 8354, NE 1/4, Sec. 33, T. 3 N., R. 4 E.; crossed nicols, x.

D. Typical abraded overgrown quartz grain in spar cement with algal limestone clast at lower left; NE 1/4, Sec. 19, T. 1 S., R. 2 E.; crossed nicols, 100 x.



A. B.

C. D.

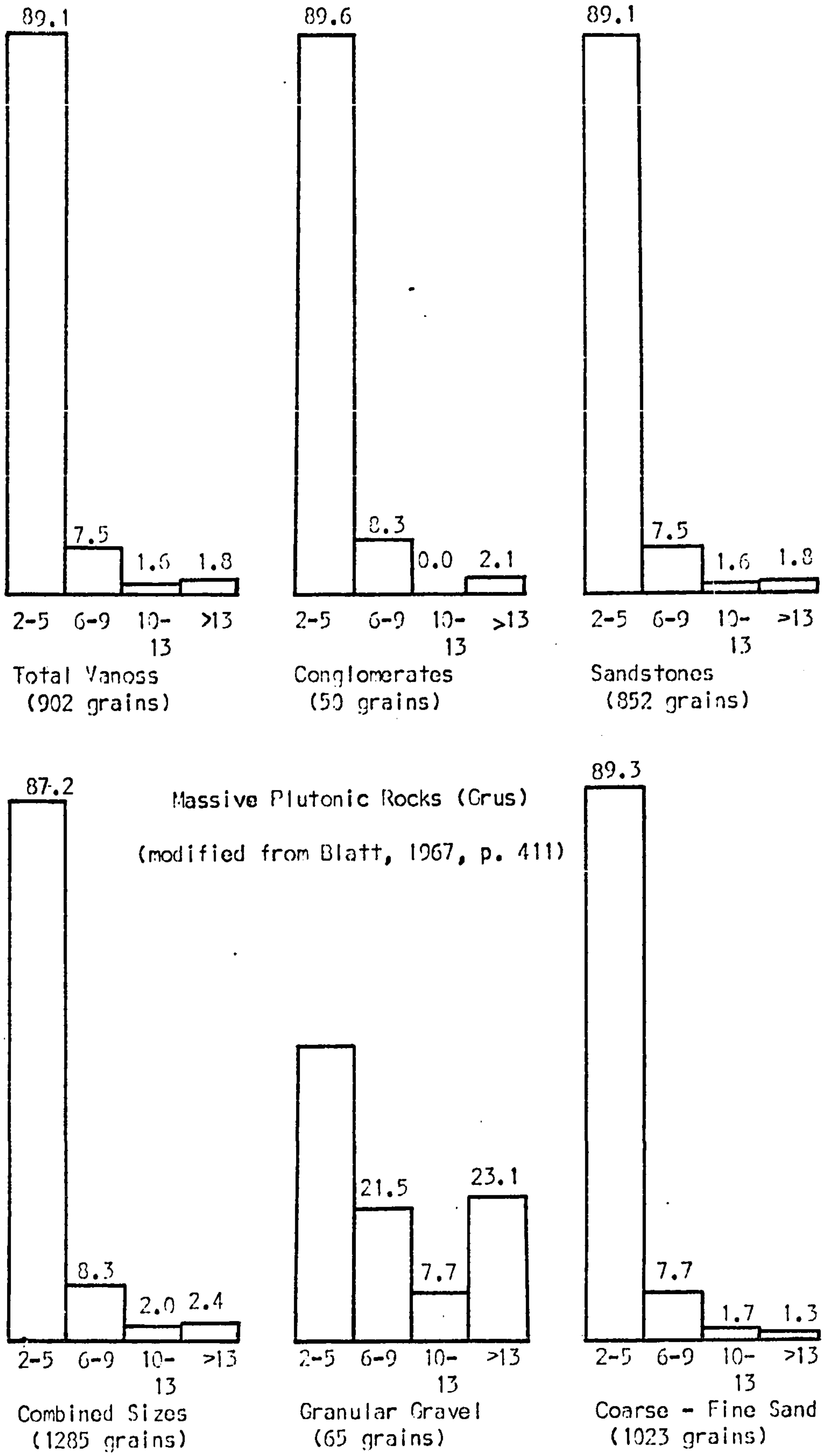


Figure 8. Comparative percentages of polycrystalline quartz grains (ordinate) versus number of crystals per grain (abcissa).

quartz (polycrystalline) in disintegrated granite "grus" was composed of not more than five crystals. In both studies (see fig. 9), a decrease in average grain size corresponded with an increase in the amount of polycrystalline quartz composed of less than five crystals. Also, total amounts of polycrystalline quartz in both studies decreased with grain size.

Polycrystalline quartz ranged in size between -0.5 Ø (1.5 millimeters) and 2.7 Ø (about 0.15 millimeters), whereas in the grus of this Tishomingo and Troy granites the size range was -1.2 Ø (2.2 millimeters) to 0.0 Ø (1.0 millimeter). The largest polycrystalline quartz grains noted in the Vanoss occurred in T. 3 N., R. 4-5 E. and the smallest grains were present in T. 11 N., R. 6 E. The difference in grain size for this quartz variety between the grus of the plutonic source rock and the derived sedimentary rock suggests breakage during transport.

It should be noted that determination of the numbers of crystals in polycrystalline grains was made using a petrographic microscope with a flat stage. Boundary relationships between crystals and optical orientation were carefully watched in order to properly identify the number of crystals.

Since the distribution map of polycrystalline quartz shows the maximum concentration in T. 3 N., R. 4 E., it suggests that the igneous source was probably exposed to the east of the outcrop area and not 30 miles to the south where the core granites are presently exposed. The concentration of polycrystalline quartz decreases away from the T. 3 N., though the overall grain size for the Vanoss rocks changes;

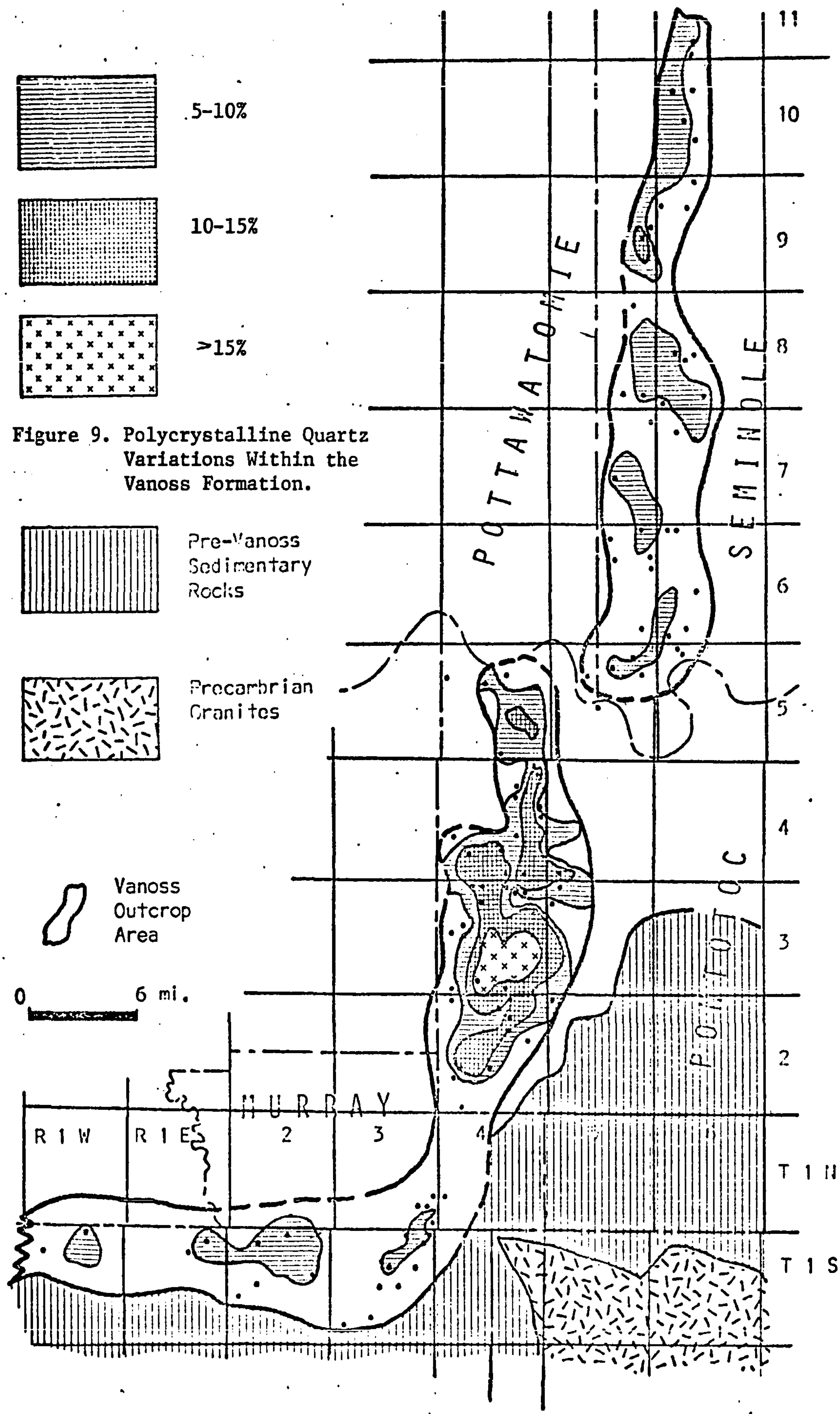


Figure 9. Polycrystalline Quartz Variations Within the Vanoss Formation.

increasing southward and decreasing northward.

Feldspar

Approximately 12.5 per cent of the grains (4,504) in the Vanoss thin-sections are feldspar. Distribution of the types recorded was: twinned plagioclase, 27 per cent; perthite, 24 per cent; microcline, 10 per cent; Carlsbad-twinned orthoclase, 7 per cent; and altered or untwinned feldspar, 31 per cent. The latter category included grains for which positive identification could not be obtained due to alteration or small grain size. It is likely that most of the 31 per cent untwinned feldspar is orthoclase since untwinned plagioclase is characteristic of metamorphic rocks which are known only as inclusions in the mesozone granites making up the core of the Arbuckles.

These observed abundances of feldspars in the Vanoss may be realistically reflecting the silicic igneous source rock mineralogy (Folk, 1968, p. 83) since the Troy and Tishomingo granites are largely composed of microcline and sodic plagioclase, much of which is present as microcline-perthite (Ham, Denison and Merritt, 1964, pp. 130-134). However, Wedepohl (1969, p. 243) found that plagioclase is more abundant than potassium feldspars in the suite of plutonic rocks he studied, including mafic as well as silicic plutonics.

Only 124 of the 147 thin-sections examined contained any feldspar. Grain size in the Vanoss sedimentary rocks sampled ranged between -0.1 Ø and 3.2 Ø with mean size of 1.74 Ø and standard deviation of 1.41 Ø. The feldspar grains were more angular (1.8) than quartz (2.2) probably because of the lower mechanical and chemical

not replicable difference

durability of feldspar under normal conditions of weathering and transport. In the grus from the Tishomingo and Troy granites, feldspar grains averaged -0.5 ∅ in size; much larger microcline-perthite crystals were quite evident in aplite veins in the Tishomingo granite. The average grain size for feldspar grains is less than that of polycrystalline quartz in the grus.

It is seen in Figure 10 that the largest feldspar clasts are found in the eastern portion of the Vanoss outcrop belt and this suggests at least one source area was east of the outcrop of Vanoss rather than to the south as suggested by Ham (1970). When feldspar grain size variation is compared to the total distribution of feldspar concentrations in the Vanoss (see figs. 11 and 13), it is again seen that an eastern source is suggested. The presence of the coarsest feldspars (mostly microcline-perthite) does not correspond to the highest total feldspar content. The logical assumption is, therefore, that greater concentrations of feldspar and coarser feldspar grain size would be located closer to the source but it appears structurally impossible to derive these clasts from an area in T. 3-4 N., R. 5-6 E.. Probably the source area is to the southeast (e.g. T. 1 S., R. 5-6 E.).

Grains of plagioclase feldspar were also identified as to twin types: albite, Carlsbad, albite-Carlsbad and "others." All grains for which it was not possible to determine one of the twin laws above, or if the feldspar was not twinned, it was counted in the "others" category. Since each slide was received from the manufacturer with a cover slip cemented on with epoxy resin, it was impossible to identify the different feldspar twin types by staining techniques.

It is seen in Table 3 that the distribution of twin types in the Vanoss closely approximates that of Slemmons' metamorphic rocks.

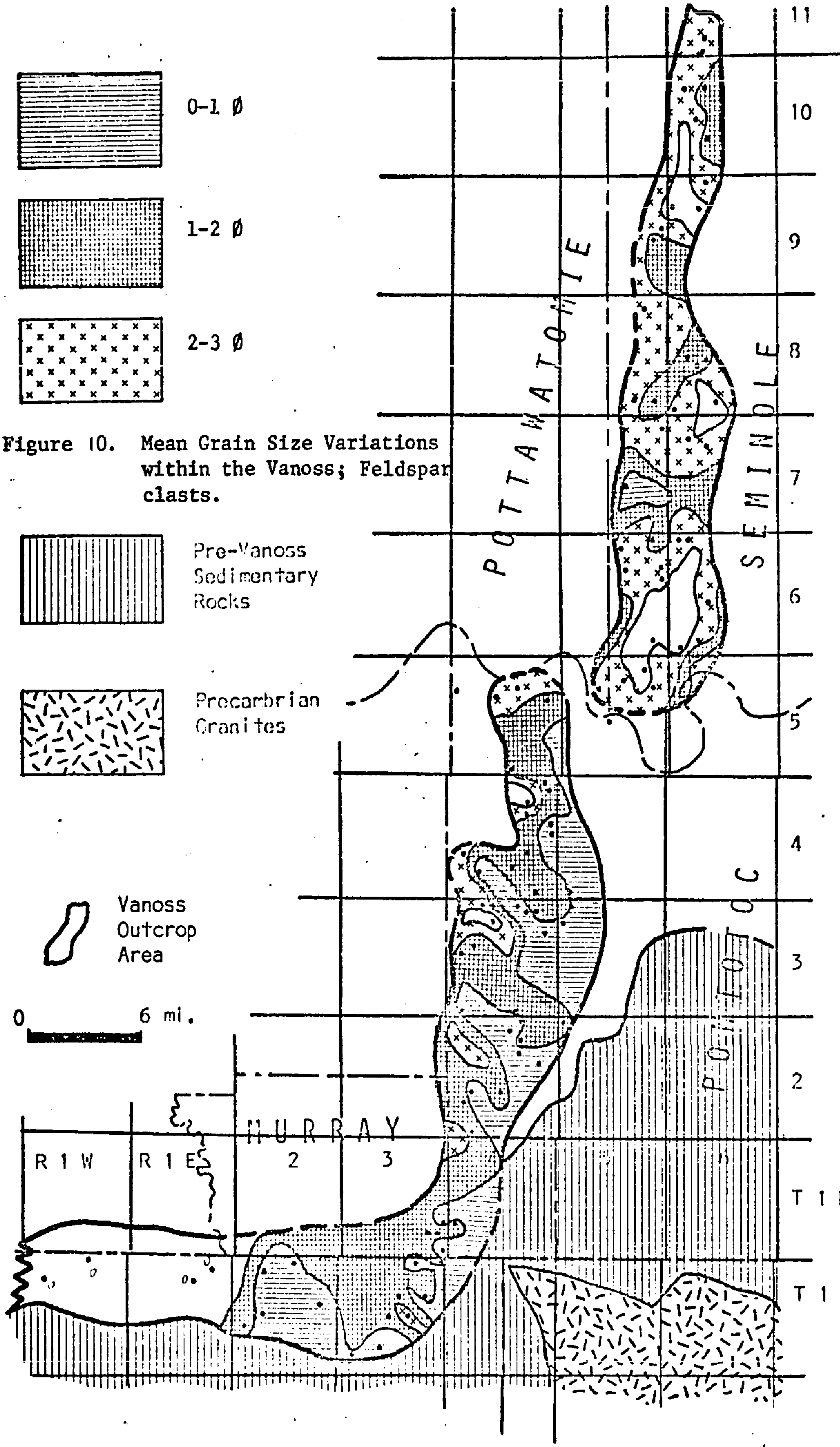


Figure 10. **Mean Grain Size Variations within the Vanoss; Feldspar clasts.**

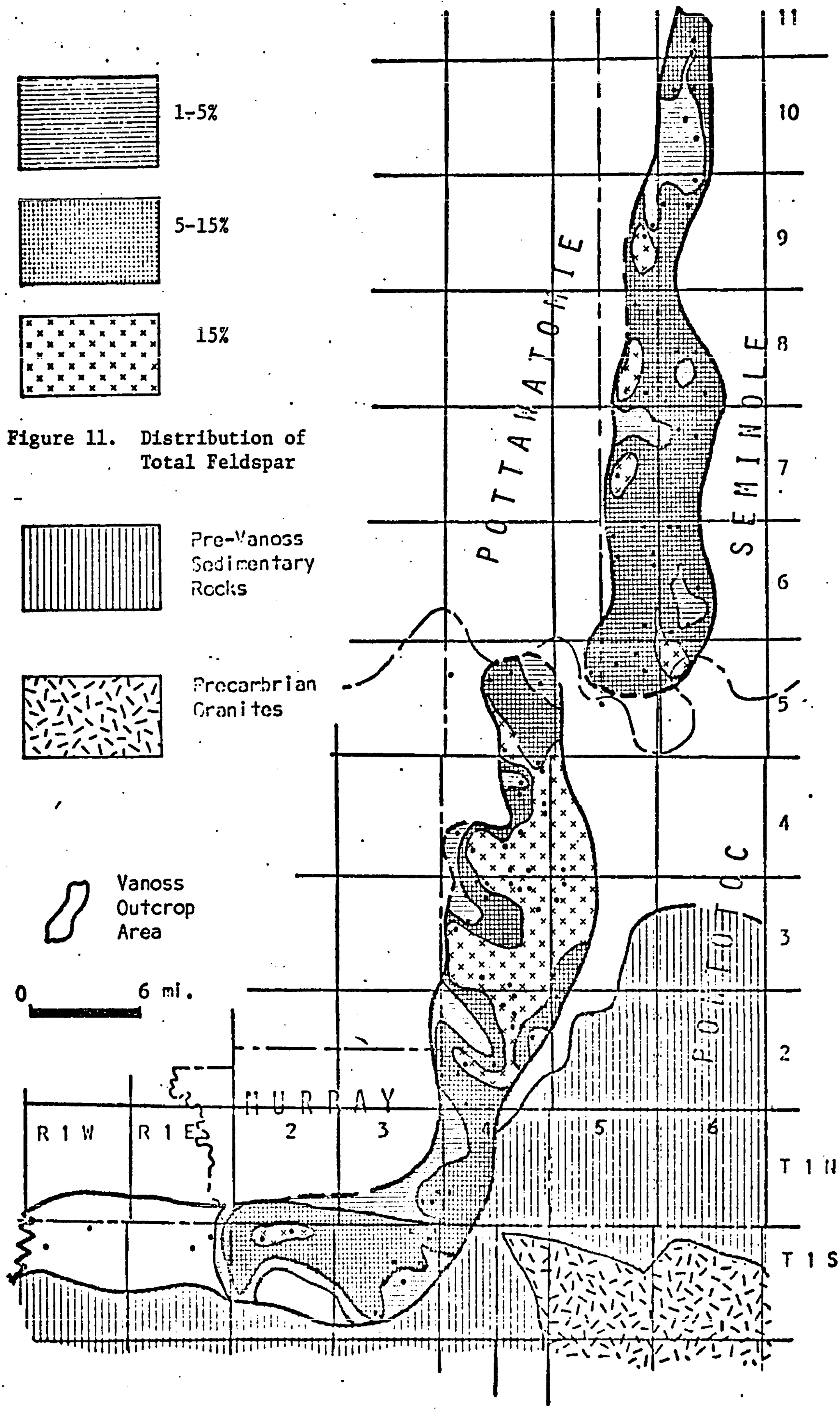


Figure 11. Distribution of Total Feldspar

TABLE 3

RELATIVE FREQUENCY OF OCCURRENCE OF PLAGIOCLASE TWIN TYPES

Twin Type	Comments	Approximate percentage of Twins by Mode of Origin[a]		Approximate percentage of Twin Types in Vanoss Samples
		Igneous	Metamorphic	
Albite	Usually with polysynthetic twinning	45	62	79
Carlsbad	Usually with two or three subindividuals	25	4	8
Albite-Carlsbad	. .	12	3	3
Others	Includes all others	18	31	10

[a]Slemmons, D. B. 1962. Determination of volcanic and plutonic plagioclases using three- or four-axis universal stages. Geol. Soc. America Spec., Paper 69. 64 pp.

The probable reason for the lack of similarity to the igneous rock data of Slemmons is that combined albite-Carlsbad twins disintegrate along the albite composition (010) planes, which are also the Carlsbad twin composition planes. Thus, as fewer Carlsbad twins occur with continued disintegration during transport, the relative abundance of albite increases. Spar replacement along the (010) planes could also enhance this change. Indeed, as distance from the assumed southeastern or eastern source increases, and grain size decreases, the relative abundance of albite twins increases; this is suggested somewhat in Figure 12.

Pericline twinning was noted in some plagioclase grains but this twin surface is at a slight angle to the (001) cleavage surface and might have been misidentified as albite twinning in grains whose boundaries were highly corroded; therefore, any grain having any angular (apparent) relationship to an assumed cleavage surface was counted in the "others" category.

Microcline-perthite intergrowths and perthite are quite common in the source graintes. During thin-section examination of samples of weathered granite and granite grus, it is seen that the formation of clay minerals (especially kaolinite) is more extensive in the albite portion of either composite grain. The same distribution of clay minerals was also observable in the microcline-perthite or perthite clasts in the Vanoss thin-sections.

A distribution map of microcline-perthite and perthite (see fig. 13) shows that maximum concentration is centered about T. 3 N., R. 4 E. and decreases in a pattern suggestive of fluvial channels flowing from an eastern-southern highland area and corresponding very well with the variation in the overall feldspar concentration of the Vanoss.

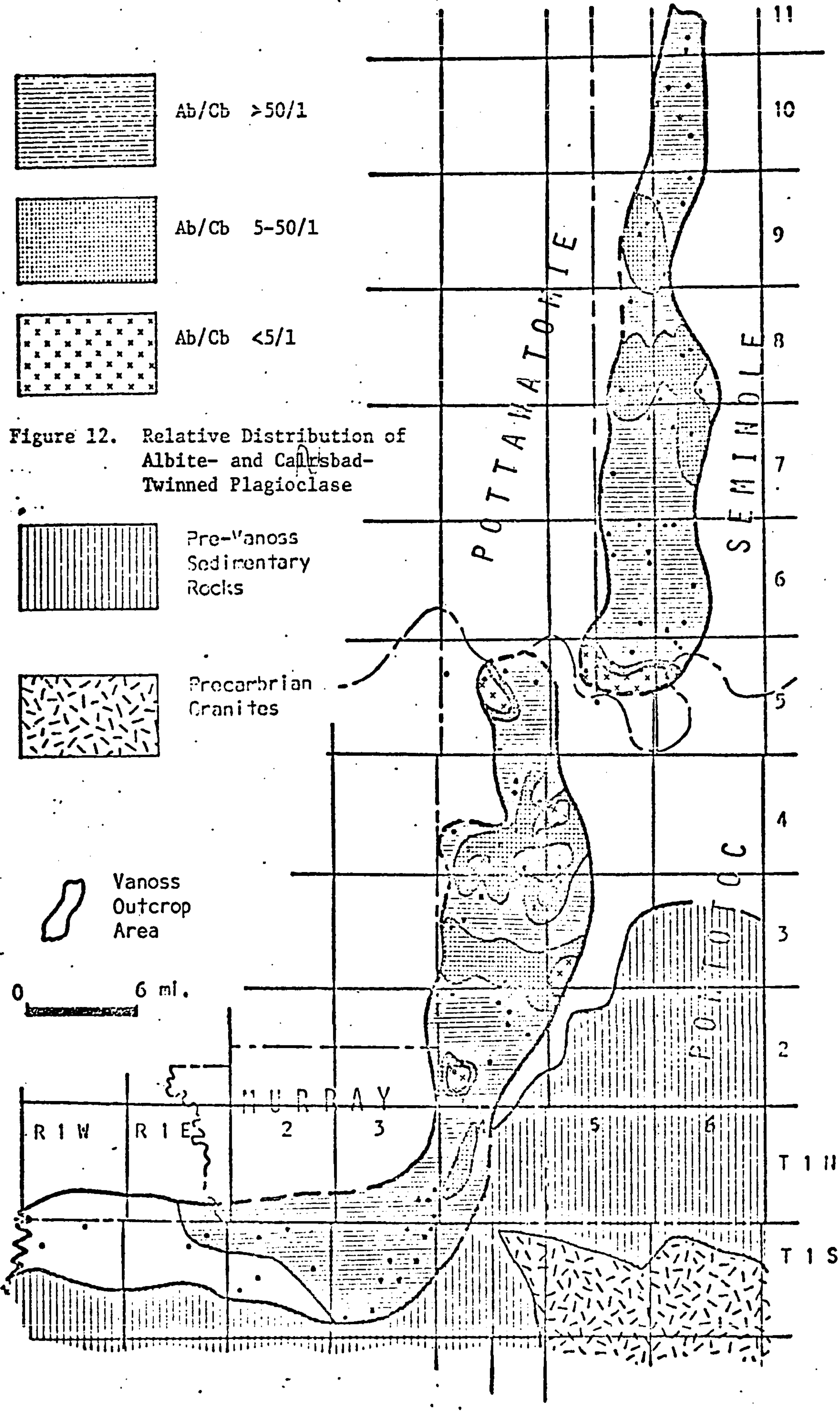


Figure 12. Relative Distribution of Albite- and Carlsbad-Twinned Plagioclase

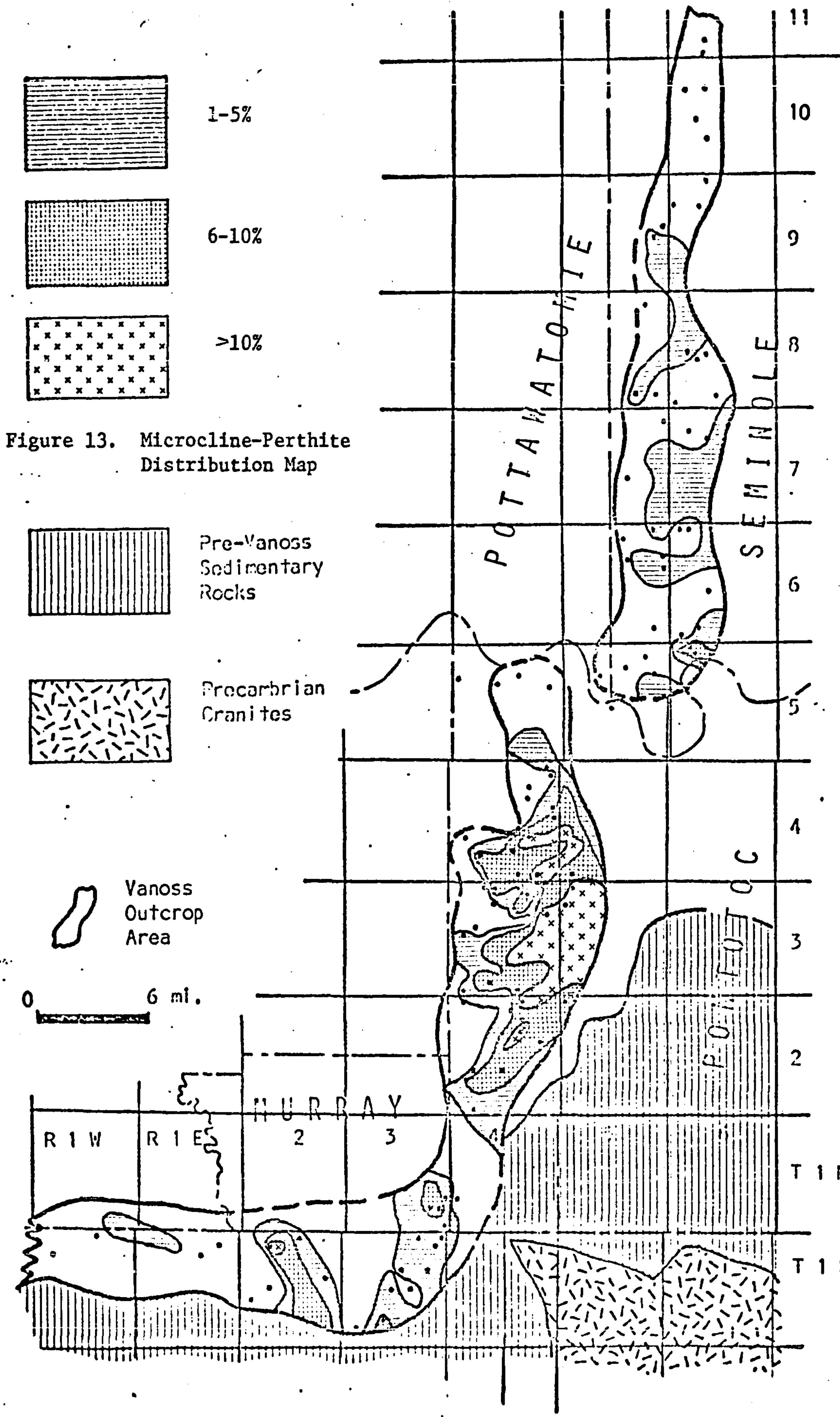


Figure 13. Microcline-Perthite Distribution Map

A ratio map of these macro-varieties of feldspar as a fraction of the total feldspar (i.e. per cent perthite/per cent total feldspar), shows that those species decline rapidly as a major segment of the feldspathic component within 30 or 40 miles of the inferred eastern or southeastern igneous source (T. 3-4 N., R. 5 E. or to the south); see Figure 14.

Lithic Fragments

The chief rock fragments were of limestone and chert (SRFs), and granite (GRFs). No systematic measurements of size or roundness variations of the SRFs were made but were made on the GRFs. Each type is discussed separately.

Limestone clasts were almost always rounded; i.e., roundness values greater than four (Folk, 1968, p. 1). Less rounded limestone clasts occurred where extensive replacement by sparry calcite or iron-rich clay was evident. Most of these clasts were concentrated in conglomerates and sandstones in portions of T. 1 S. and T. 1 N. (see fig. 15). With few exceptions, no limestone fragments were present north of T. 5 N., R. 5 E., 35 miles from the presently exposed lower Paleozoic limestone source rocks .

Chert rock fragments, however, are present throughout nearly the entire outcrop area (see fig. 16). Examination of loose clasts and thin-sections of Vanoss rocks reveals that the chert ranges in size between -4 Ø and 2 Ø and tends to be less rounded and spherical (measured on pebbles) in smaller-sized clasts. Examination of chert grains picked from randomly selected samples and studied using a binocular microscope showed that smaller grains (less than 2 Ø) appeared more platy.

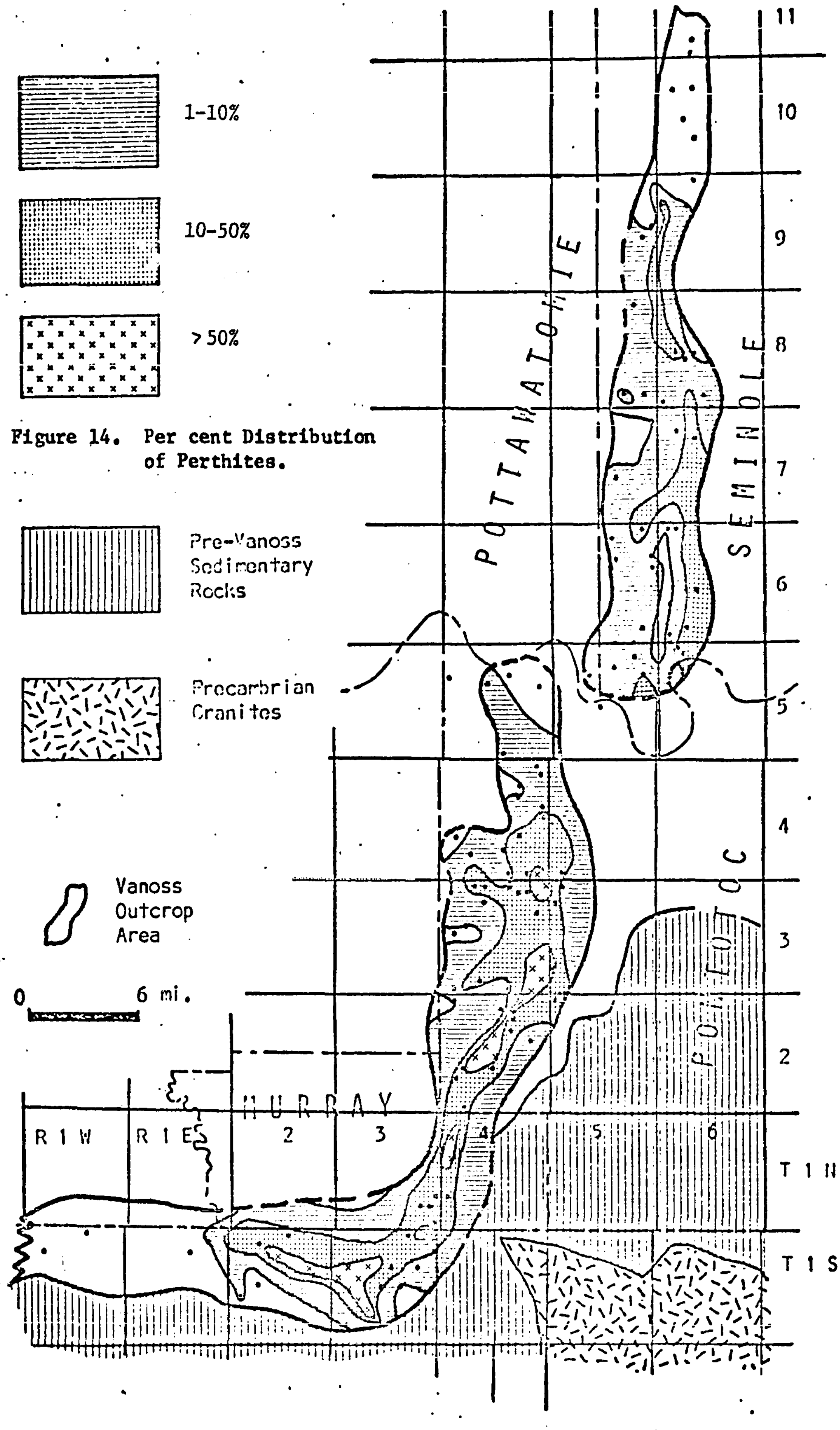


Figure 14. Per cent Distribution of Perthites.

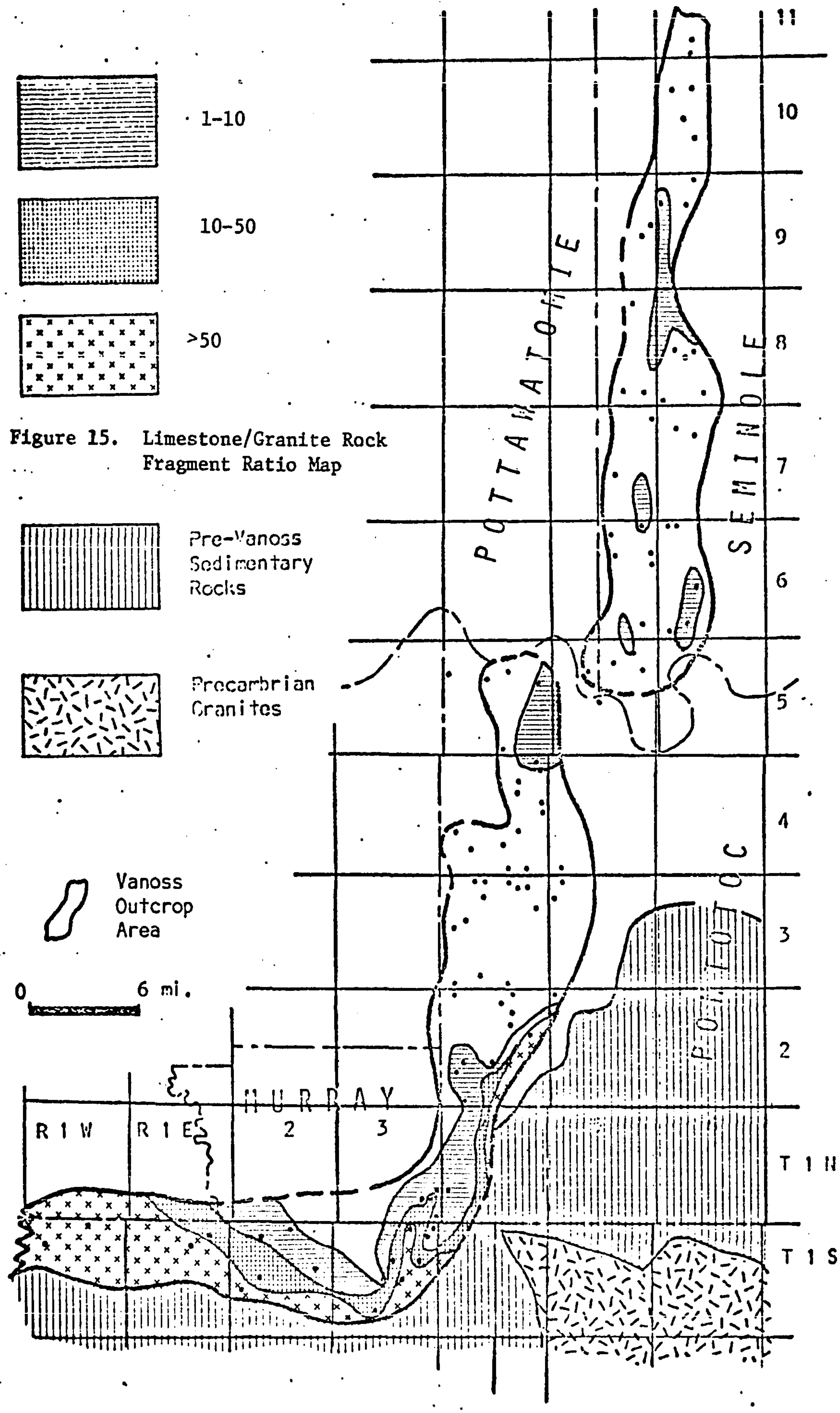


Figure 15. Limestone/Granite Rock Fragment Ratio Map

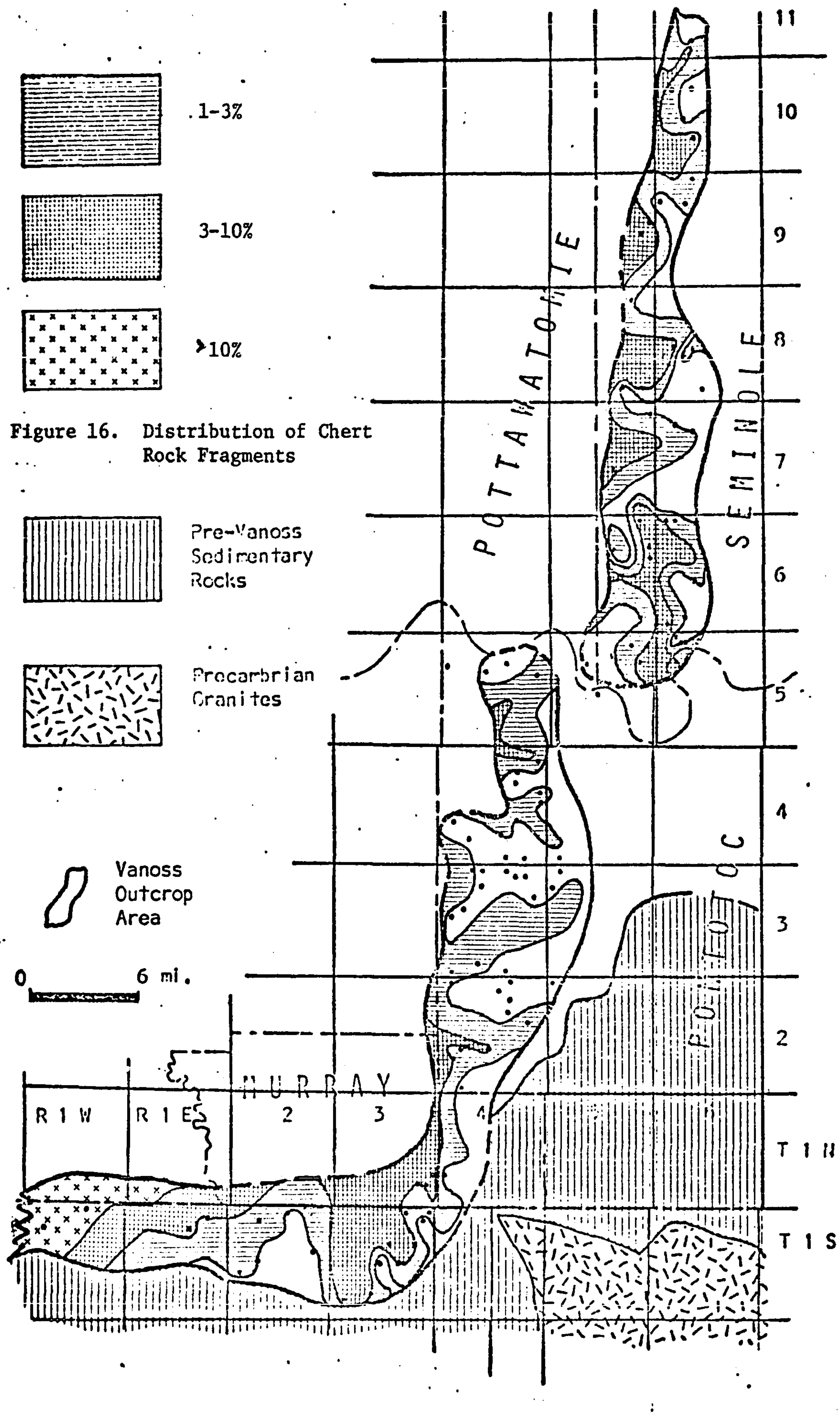


Figure 16. Distribution of Chert Rock Fragments

Thin-section observations of randomly selected conglomerate (T. 1 S., R. 3 E.), arkosic sandstone (T. 5 N., R. 4 E.), and subarkosic sandstone (T. 8 N., R. 5 E.) samples showed that Folk roundness decreased from 3.5 to 2.2 and ultimately to about 1.8 with decreasing grain size moving northward in the outcrop belt.

The decrease in roundness with decreasing grain size may be due to the smaller grains (1 Ø or less) fracturing along bedding planes and becoming more angular, while pebbles or cobbles of chert may continue to be rounded because of abrasion during traction or saltation transport.

In every thin-section containing chert south of T. 5 N., some of the chert clasts contain dolomite molds. In Seminole County (T. 6 N., to T. 11 N.) a few of the chert grains contain length- slow chalcedony, a characteristic which Folk and Pittman (1971, p. 1045) say is indicative of evaporite associations. It is seen by comparison of Figures 15 and 16 that chert is more durable than limestone during transport.

Granite rock fragments are present throughout a much greater portion of the Vanoss than are limestone rock fragments. A comparison of the limestone rock fragment and granite rock fragment ratio map (fig. 15) and the granite rock fragment mean grain size map (fig. 17) indicates that concentrations of limestone clasts correspond to smaller sizes and lesser amounts of GRFs. If the two had been derived from the same local source area, clearly the size reduction of limestone would be seen as greater than that of the igneous-derived material (a function of rock type).

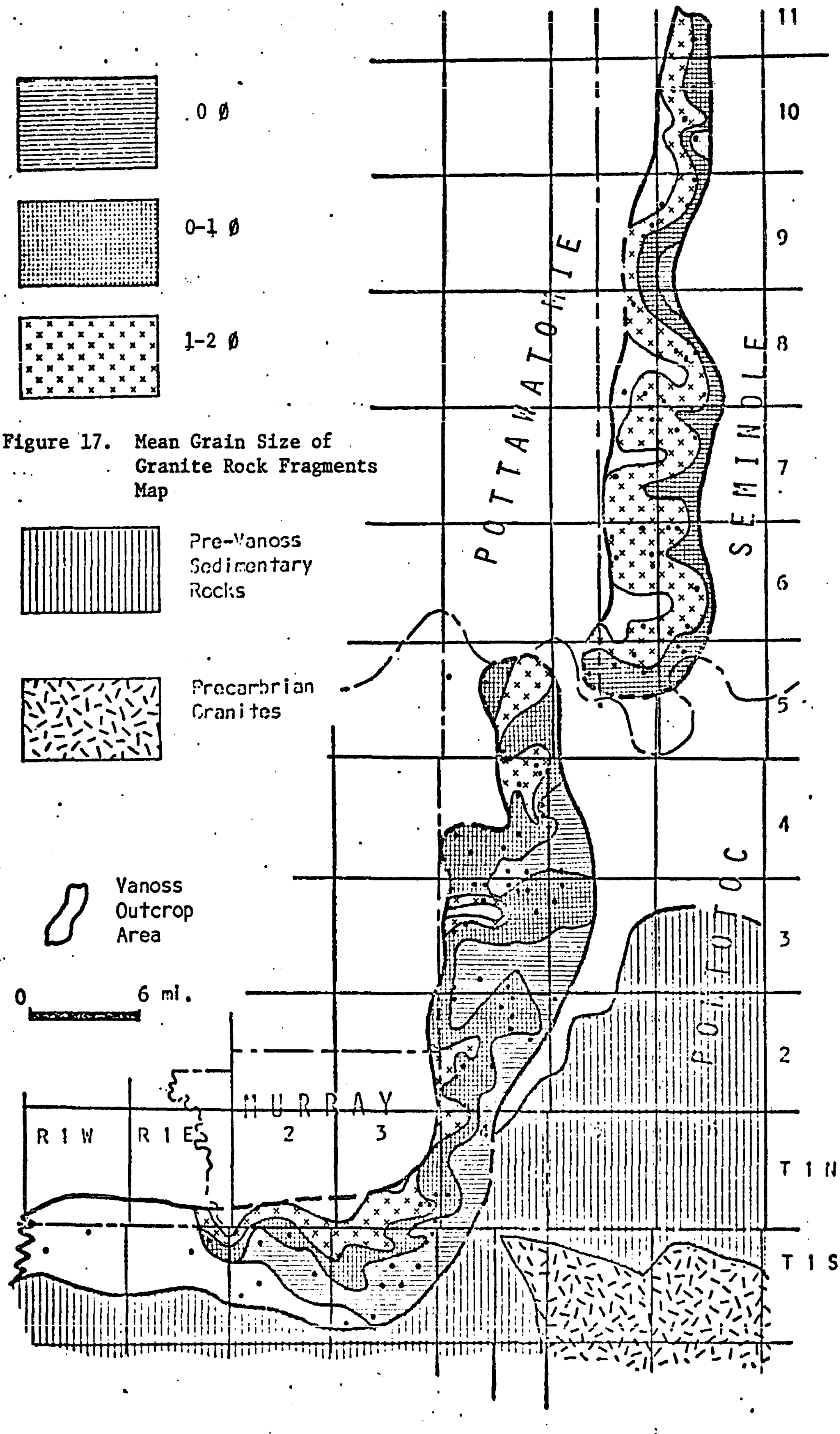


Figure 17. Mean Grain Size of Granite Rock Fragments Map

Mean grain size of granite rock fragments was 0.74 ϕ and ranged between -1.1 ϕ and 2.2 ϕ (standard deviation 1.7 ϕ) compared to -1.1 ϕ mean grain size for granite rock fragments in the grus. The greatest concentrations of GRFs in the Vanoss are located in two areas: T. 3-4 N., R. 4-5 E. and T. 1 S., R. 3 E. (fig. 15). This is similar to the distribution of microcline-perthite (see fig. 14) in that there are a few coarse grains in T. 1 S., R. 3 E. and a greater concentration in T. 3-4 N. The latter area also corresponds to maximum grain sizes and concentrations of feldspar and quartz.

Mean roundness of these clasts was 1.96 (slightly angular) for the GRFs in the Vanoss versus 1.50 (angular) in the grus which suggests that rounding does occur with transportation along with disintegration. The lack of sufficient numbers of GRFs in many slides, however, precludes statistical proof of such an observation. Graphic intergrowths of quartz and feldspar become relatively more common as the size of the GRFs decreases.

Other rock fragments noted in the thin-sections were hematitic orthoquartzite (T. 1 S., R. 1 W. and R. 1-2 E.), shale (T. 8 N., R. 6 E.), fine-grained quartzose sandstone, volcanic rocks, dike rocks and schist fragments. Their distribution followed no distinct pattern with concentrations of each type not exceeding 2 per cent (6 points) in any slide. The red sandstone fragments are presumably from the Cambrian Reagan Formation as they most closely resemble that lithology. The volcanic rock fragments are thought to be from the Middle Cambrian Colbert Rhyolite Porphyry. Dike rock fragments (highly weathered) are from diabase dikes (G. T. Stone, personal communication) transecting the Troy granite, while the schist fragments must be from inclusions or xenoliths in the granites. Shale fragments and the fine-grained, iron-free sandstone are probably from erosion of Vanoss floodplain deposits evident in T. 7-8 N., R. 6 E.

Because of extensive alteration and iron-staining, the volcanic and diabase rock fragments are difficult to describe. Both contained occasional polysynthetically-twinned plagioclase and regions of "macrochert" texture as well as coarse flakes of kaolinite. Greatest concentration of dike rock clasts seemed to be T. 3-4 N., R. 4 E.

Cementing Agents

Four types of cement were identified in thin-sections of the Vanoss Formation rocks: coarse sparry calcite, fine-grained spar (4-10 microns), iron-stained kaolinite and siderite. In the case of the kaolinite, identification of the clay was confirmed by X-ray diffraction. Few of the thin-sections were wholly indurated by a single cementbut one cement was usually dominant. A distribution map of the most abundant cementing agent in each thin-section (see fig. 18) indicates that two distinct broad zones of cement type are present; in the region south of T. 5 N., the cementing agent is predominantly coarse or fine sparry calcite, to the north, kaolinite is most abundant.

North of T. 5 N., calcite is widely present but only in minor concentrations. It occurs as occasional void fillings in the iron-stained clay or as a partially replaced (by the clay) coating on a few clasts. Occurrences of siderite are limited to a few areas in which

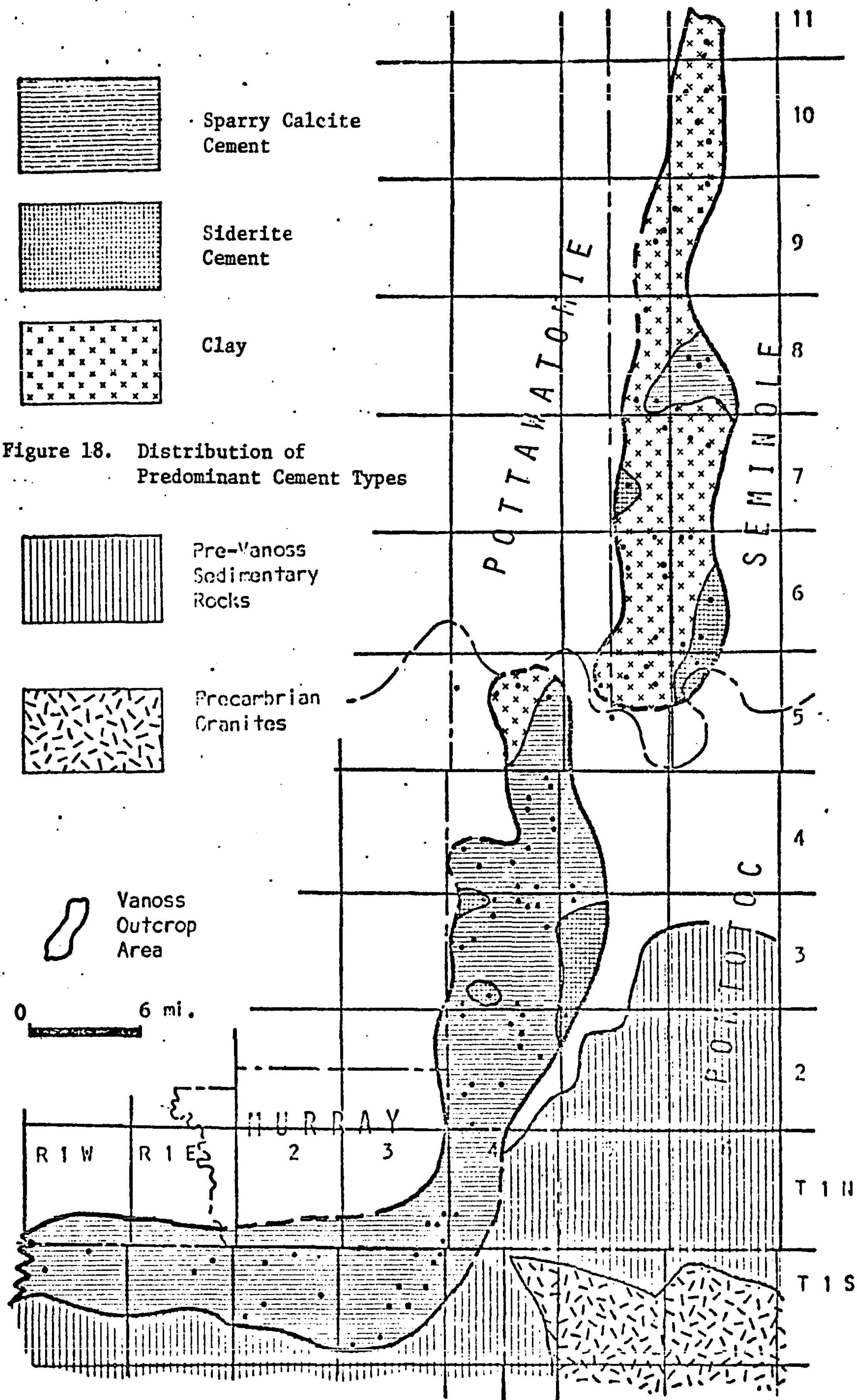


Figure 18. Distribution of Predominant Cement Types

pyrite was often found in association.

A second type of clay cement, illite (?), is irregularly found in the northern portion of the outcrop area. It occurs as a thin coating on surfaces of sand-sized clasts. The coated grains show less replacement by the iron-stained clay than do grains on the same slide which are not protected by the layer. X-ray diffraction indicates the presence of traces of illite in the suspect samples, otherwise the identification of the coatings is by optical means. For such grain coatings Brewer (1954) has used the term "cutan" and reports that it is a phenomenon which occurs by precipitation from circulating fluids in soil profiles. I have concluded that this is a modern soil-forming process since a study of Vanoss clastics as penetrated in four core holes in the area showed that at a depth of 100 to 140 feet the cutan is not present (see Appendix B). I have noticed no unusual mineralogic inversions related to the cutan and, therefore, conclude that it has not affected my data. There is no indication that it is detritus derived from a non-Arbuckle source area.

Interpretation of Cements

The geochemical parameters affecting precipitation of the different cements no doubt involve more than changes in Eh and pH (Garrels and Christ, 1965, p. 396) but these parameters are useful as a general framework by which associations might be explained. It may be hypothesized that the limestone detritus carried downslope from the Arbuckle highlands raised the pH of the groundwaters and the Ca^{++} and $CO_3^{=}$ ionic concentrations, especially south of T. 1 S. where much of the lower Paleozoic carbonates were exposed. In examination of thin-sections, it is seen that many of the clasts in the southern portion have been initially cemented by fine sparry calcite and toward the center of the pore space it recrystallizes to a coarser spar. This could be explained by initial precipitation of calcite under increasing pH and later recrystallization to coarse spar as the Vanoss was flushed by groundwaters.

There is evidence, however, that some of the fine spar has recrystallized from micrite. In one area centered around Sec. 14, T. 1 S., R. 2 E., the finely-crystalline spar is associated with algal-coated grains and scattered pelmatazoan plates, indicating that a portion of the Vanoss was deposited in marine conditions. Ham (1969, p. 17) did not mention possible marine deposition for the Vanoss but does indicate that portions of the Ada Formation were deposited in marine conditions on the western side of the Hunton Anticline as the anticline began to emerge in early Desmoinesian time. Barring other evidence for the marine aspect of Vanoss deposition, it seems that the Vanoss bordered a saline lake and that the "microspar" may be recrystallized micrite mud (Folk, 1965, p. 37).

As the Vanoss becomes more arkosic northward, the amount of carbonate cement diminishes and is replaced by iron-stained kaolinite. In the analysis of natural waters from arkosic sediments, Garrels and Christ (1965, pp. 357, 361) show that the formation of kaolinite depends upon concentrations of the following ionic species: AlO_2^-, Al^{3+}, H^+ and H_4SiO_4. pH values between 4 and 10 are necessary for kaolinite precipitation and such a range brackets the pH of arkosic waters according to Garrels and Christ.

Besides precipitation from fluids, kaolinite formed from detrital illite by leaching of metallic cations as evidenced by the traces of illite present only in the less permeable rocks wherein leaching has been retarded.

Siderite (ferrous iron) is not a common cementing agent in terrigenous clastics. Stable only under negative Eh conditions, it is present in the Vanoss in association with small amounts of pyrite (ferrous iron) and the iron-stained clay (ferric iron). It is likely that locally negative Eh conditions prevailed but later leaching has removed much of the siderite with the iron-stained clay resulting. Keller (1958, p. 243) points out that local occurrences of negative Eh with near neutral pH is likely accomplished with organic decay; a likely environment would be a floodplain bog. The overall paragenesis of the Vanoss is described in the final chapter of this paper.

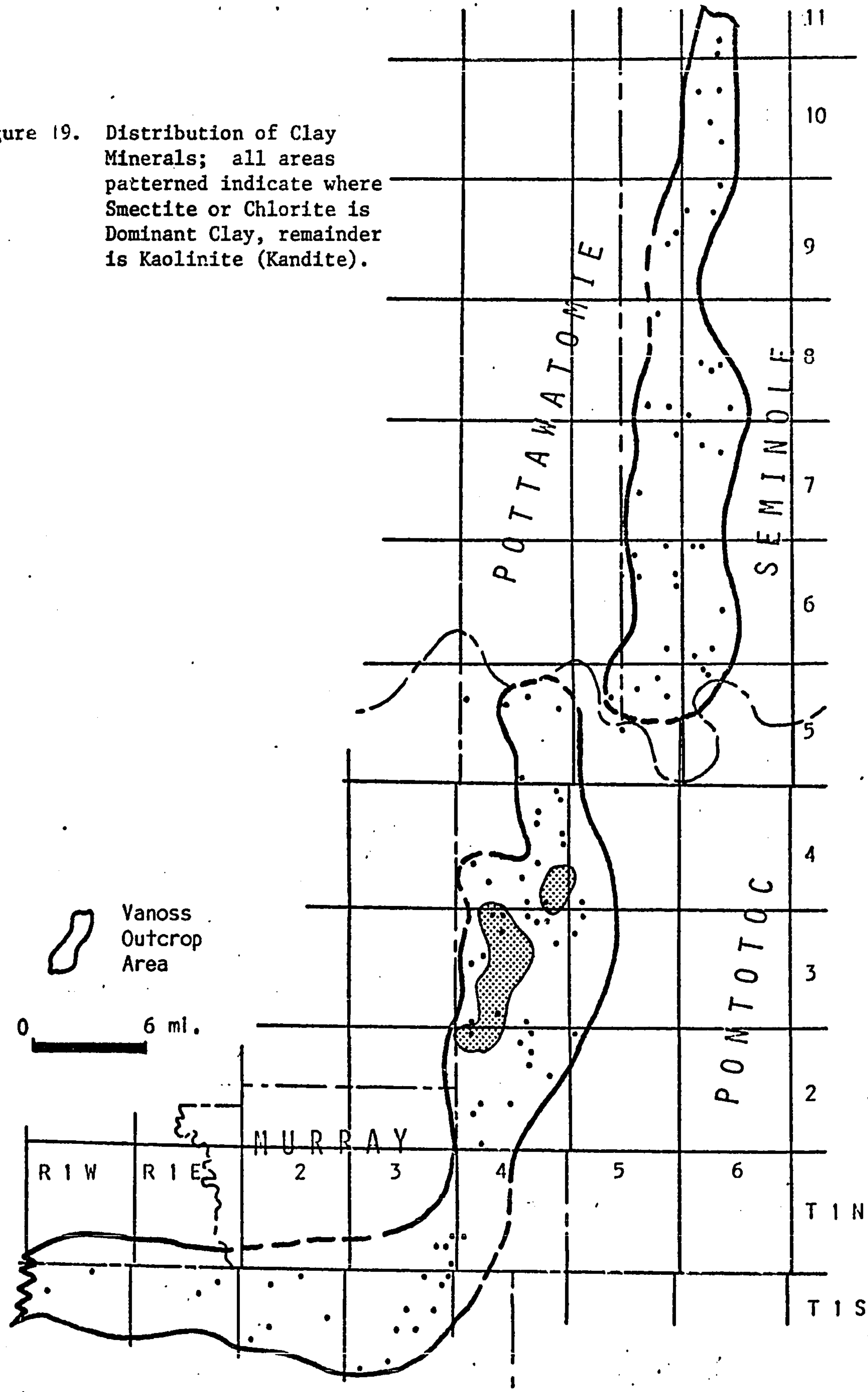
CLAY MINERALOGY

Determination of the clay mineral suite of the Vanoss Formation is based on analysis of 137 thin-sections and X-ray diffraction studies of 147 samples. In addition to these samples, sedimented slides were made of ten samples of shale in order to compare their clay mineralogy with that of associated sandstones.

The dominant clay mineral present in both sandstones and shales is a moderately well-crystallized kaolinite. Lesser amounts of illite, montmorillonite, chlorite (?) and mixed-layer illite-montmorillonite were also found. X-ray diffraction patterns of shales consistently show greater relative amounts of illite and montmorillonite than in the coarser clastic rocks, presumably because of better circulation (leaching) of fluids in sandstones. Only seven samples (see fig. 19) contained another mineral (montmorillonite) rather than kaolinite as the dominant clay.

In Vanoss thin-sections, clay minerals appear in several distinct habits which are related to their mode of formation. They appear as laths in crystals of feldspar, as disseminated flakes in the matrix of conglomerates or limestones; and as masses of heavily iron-stained material surrounding clasts in the medium or finer grained sandstones. Illite also appeared as a "cutan" coating coarser clasts

Figure 19. Distribution of Clay Minerals; all areas patterned indicate where Smectite or Chlorite is Dominant Clay, remainder is Kaolinite (Kandite).



in Vanoss samples collected from the soil profile as mentioned previously.

Thin-section study showed a sequence of feldspar alteration in samples, excluding limestones or conglomerates, as follows:

1. Initial alteration of plagioclase to kaolinite in the source rock and grus.
2. Alteration of microcline and orthoclase to kaolinite (with iron oxide) in the sediments.
3. Kaolinite forms by alteration of detrital clay minerals or remaining feldspar clasts in the sedimentary rocks.

Alteration to elongate kaolinite laths is evident in most of the feldspar crystals in the grus (thin-section number 7057) and in the fresh source rock. The kaolinite is rather coarse with some crystals reaching a length of 10 microns; many crystals being oriented parallel to the (010) and (001) cleavages in the host feldspar grains. Perthite grains in the Vanoss exhibit preferential breakage in the more highly altered albitic zones.

The second stage of clay mineral generation is a continued replacement of previously altered feldspar clasts. Laths of kaolinite generated in this stage are not as coarse and all altered grains are enclosed by spar cement. The second generation of clay minerals probably began during transport and continued after deposition.

Frequently pieces of perthite in the Vanoss (e.g. thin-section number 5575) exhibit irregular breakdown. The albitic portion of the grains has already been extensively altered to clay and are softer but the potassium-rich phase now exhibits tiny crystals of kaolinite, too.

In areas of lesser cementation by carbonate, heavily iron-stained masses (and some euhedra) of clay occupy former void spaces. To identify the clay as kaolinite required X-ray diffraction. The diffractograms further showed the presence of poorly crystalline illite, montmorillonite and kaolinite in argillaceous sandstones and shales of the Vanoss.

Representative X-ray diffraction patterns (see fig. 20) illustrate previously stated variations in clay mineralogy with patterns arranged so that the bottom pattern is the most southerly sample. Criteria for identification of the various clays by X-ray diffraction are described below. The reader is referred to Grim (1958) or Brown (1961) for more detailed discussions.

Kaolinite

First, second and third order basal reflections (001) are sufficient to identify kaolinite. A two-layer dioctahedral clay, its basal spacings are 7.17 Å, 3.58 Å and 2.39 Å, respectively. These spacings are unaffected by warm hydrochloric acid (confirmed by acidizing three Vanoss samples). The kaolinite structure collapses only upon heating above 550°C (Brown, 1961, p. 253).

Dickite is a better crystallized two-layer clay with prominent (002), (004) and (006) reflections at 7.15 Å, 3.58 Å and 2.38 Å, respectively. The first two peaks are nearly identical with those of kaolinite but the intensities of the basal reflections reverse; that is,

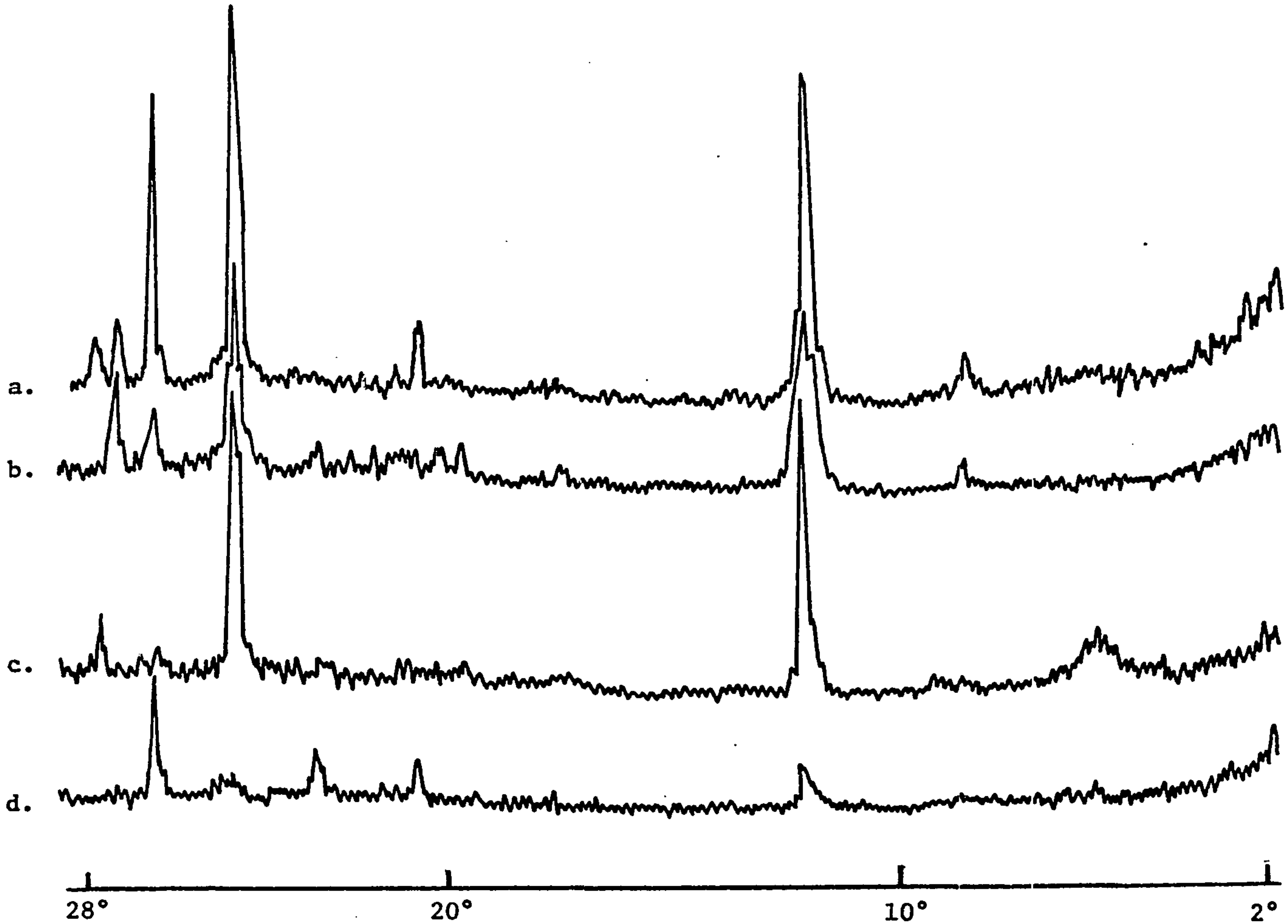


Figure 20. Representative X-ray Diffraction Patterns of Clays in the Vanoss Formation Locations: (a)NE 1/4, Sec. 10, T. 5 N., R. 5 E.; (b) NE 1/4, Sec. 13, T. 4 N., R. 4 E.; (c) NW 1/4, Sec. 3, T. 1 S., R. 2 E.; and (d) NE 1/4, T. 1 S., R. 1 E.

the 7.15 Å and 3.58 Å peaks for dickite have reported intensities of 90 and 100, while they are 100 and 80 for kaolinite (Brown, 1961, p. 115). The third order reflection (approximately 2.38 Å) is about one-fifth more intense in dickite than in kaolinite. If the two-layer clay is poorly crystallized or weathered, the shape of the peak is broader and more irregular. This is interpretable as a function of either weathering or diagenesis of kaolinite. Since dickite is a two-layer clay with much better crystallinity than kaolinite, I do not feel that this degraded two-layer clay is dickite but is kaolinite.

Illite

Illite may be identified by the presence and intensity of its (002), (110) and (006) reflections at 9.9 Å (intensity 80), 4.46 Å (intensity 100) and 3.36 Å (intensity 100). Asymmetry of the (002) peak is common and is a measure of the "degraded" nature of the illite. According to Grim (1968, p. 530), "frayed or degraded" illite forms by leaching of potassium from the structure. Illite that is degraded and possesses a broad asymmetric (002) peak may also result from the combination of initial tetrahedral charge site deficiency (Al^{3+} substitution for about 1/6 of the Si^{4+}) plus stripping off of some potassium and hydronium ions (Kerns and Mankin, 1968).

Glycolation of slides containing illite always resulted in a sharpening of the (002) peak; glycol apparently propping open the structure. More study would be necessary to determine the degree to which charge-site deficiency affects peak symmetry in illite of the Vanoss Formation.

Montmorillonite

The smectite group has various basal first-order d-spacings, from 12.5 to 15.5 Å depending on the interlayer cation and the amount of water present. Montmorillonite is an expandable three-layer clay mineral with a basal first-order spacing of about 14 Å. Diagnostic expansion of the structure to a basal spacing of 17 Å in an atmosphere of ethylene glycol is well exhibited by Vanoss samples containing montmorillonite. In a few cases, expansion to the full 17 Å spacing was accomplished only after several additional hours in the glycol vat beyond the normal 3 to 5 hours required for other samples. No explanation is offered for the difference.

Chlorite

I originally expected the presence of chlorite in some Vanoss slides because I identified small amounts of chlorite in preliminary X-ray analyses of weathered Troy granite. However, only two samples of Vanoss (numbers 46 and 99) contained detectable amounts of chlorite and both were limestones. It is possible that the chlorite was altered to kaolinite (third stage of clay mineral formation) in the more permeable samples.

Because the basal reflections of chlorite at 7.16 Å, 14 Å and 3.57 Å are similar to kaolinite, further treatment is necessary in order to identify presence of the mineral. Glycolation is nearly ineffectual and the only change upon heating to 550°C is a reversal of peak intensities due to modification of the brucite layer. In samples of the Vanoss (46 and 99) containing chlorite, the diffraction peaks disappeared when treated with warm hydrochloric acid as described by Brown and others as characteristic of that clay.

Mixed-Layer Clays

Mixed-layer clays are present in a few Vanoss samples. Their relative abundance was not determined because of the broad, low-amplitude peaks. In the few samples containing identifiable mixed-layer clays, weak super-order (?) peaks appeared at approximately 24 Ångstroms. After glycolation, those samples containing mixed-layer clays were shown to contain varying amounts of illite and montmorillonite. The rate of uptake of glycol by the montmorillonite was slow, often requiring 15 hours for total loss of the super-order peaks. For these reasons, it was felt by the writer that the mixed-layer clays present were not purely of the random layer (ABCBA) or regular layer (ABAB) types of clays as shown by Grim's work (1968, p. 120).

Areal Distribution of Clays

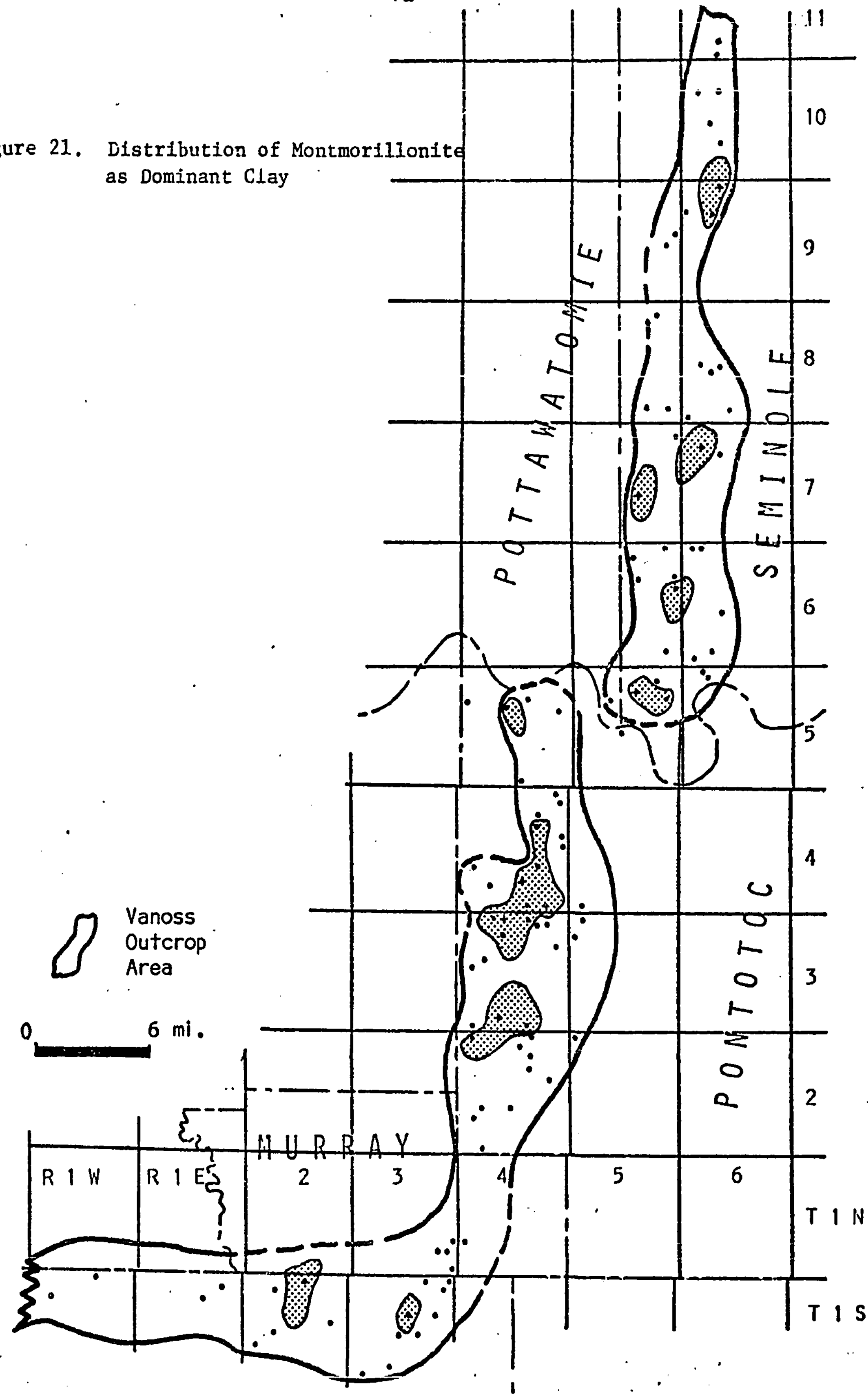
There is no systematic variation observed in calculated intensity data (see Appendix C). In the limestone cobble and pebble conglomerates close to the mountain front, the abundance of clays is low, with a poorly crystallized kaolinite the most common clay mineral. Bulk clay mineral abundance per sample increases toward the northeast as overall grain size of the Vanoss decreases. Lower stream velocities on the Vanoss alluvial fans and deltas originally concentrated the clays with other finer-grained clastics but post-depositional leaching has burther modified the clay mineral distribution.

Montmorillonite is the dominant clay mineral in only one area (see fig. 19) but is evident in samples from other portions of the outcrop belt. The presence of montmorillonite throughout the Vanoss outcrop area (fig. 21) is strongly dependent upon the average grain size of the sediment; it is more common in shale or poorly-sorted fine-grained sandstones than in the "cleaner" sandstones and conglomerate and, therefore, is a function of the porosity and permeability of the rock.

The distribution of illite is highly irregular, being affected by both the grain size of the sediments and diagenesis (Burst, 1969). Not much illite is present, but north of T. 5 N., R. 4 E. it is present in all samples; possibly indicating a marine influence on the clay mineralogy. Centered about Sec. 1, T. 7 N., R. 5 E., the Vanoss appears to be deltaic or alluvial-fan in origin (cross laminations in sandstones containing clay galls) and grades north-northwestward into a near shore marine sequence (in the subsurface). North of the study area, where the Ada and Vanoss are mapped together, interbedded marine limestones and shales are found as Vanoss lithologic equivalents. The crystallinity of the illite increases as kaolinite crystallinity decreases; this is shown by the decay of the (003) peak and broader (001) and (002) peaks of kaolinite (Murray and Lyons, 1956).

Minor amounts of poorly crystallized 2:1 clay with a basal spacing of about 10 Å, a hydromica, are associated with the deltaic portion of the Vanoss outcrop area. Characteristically, its low-amplitude peaks at about 4.98 Å and 9.9 Å sharpen with glycolation

Figure 21. Distribution of Montmorillonite as Dominant Clay



and collapse upon heating (see fig. 22).

North of the deltaic area, the "hydromica" appears to intergrade with a poorly crystallized illite-montmorillonite mixed-layer clay. Treatment with glycol sharpens the illite peak and shifts the montmorillonite peak to 17 Å, but the broad area between peaks diminishes only slightly.

The sandstones and conglomerates of T. 1 S. through 2 N., R. 3 E. are known to contain cobbles and boulders of Ordovician (Oil Creek ?) asphaltic sandstone and hydrocarbon-bearing samples of Vanoss are present in two restricted areas (see. fig. 23). Evidence of asphaltic residues is retained in the finer grain sizes, probably because of restricted groundwater motion through these sediments.

Only one sample north of the Sulphur, Oklahoma, area was asphaltic (N 1/2, Sec. 5, T. 5 N., R. 6 E.). Stratigraphically, it is about 35 feet above an asphaltic seep in the Ada Formation (Tanner, 1956, plate I) on the north bank of the Canadian River.

Vertical Distribution of Clay

The thickest exposure of Vanoss is located in an abandoned gravel pit in the NW 1/4, Sec. 30, T. 1 N., R. 4 E. Five different lithologic members are present but their clay mineralogy varies little except for the degree of kaolinite crystallinity (see fig. 24). Variations in the clay mineralogy in the Vanoss, as shown by the vertical sequence in Section 30, are governed by mineralogy, sorting and grain size of the sediment which, in turn, affects the degree of groundwater percolation. In conglomerates, the original clay mineralogy is

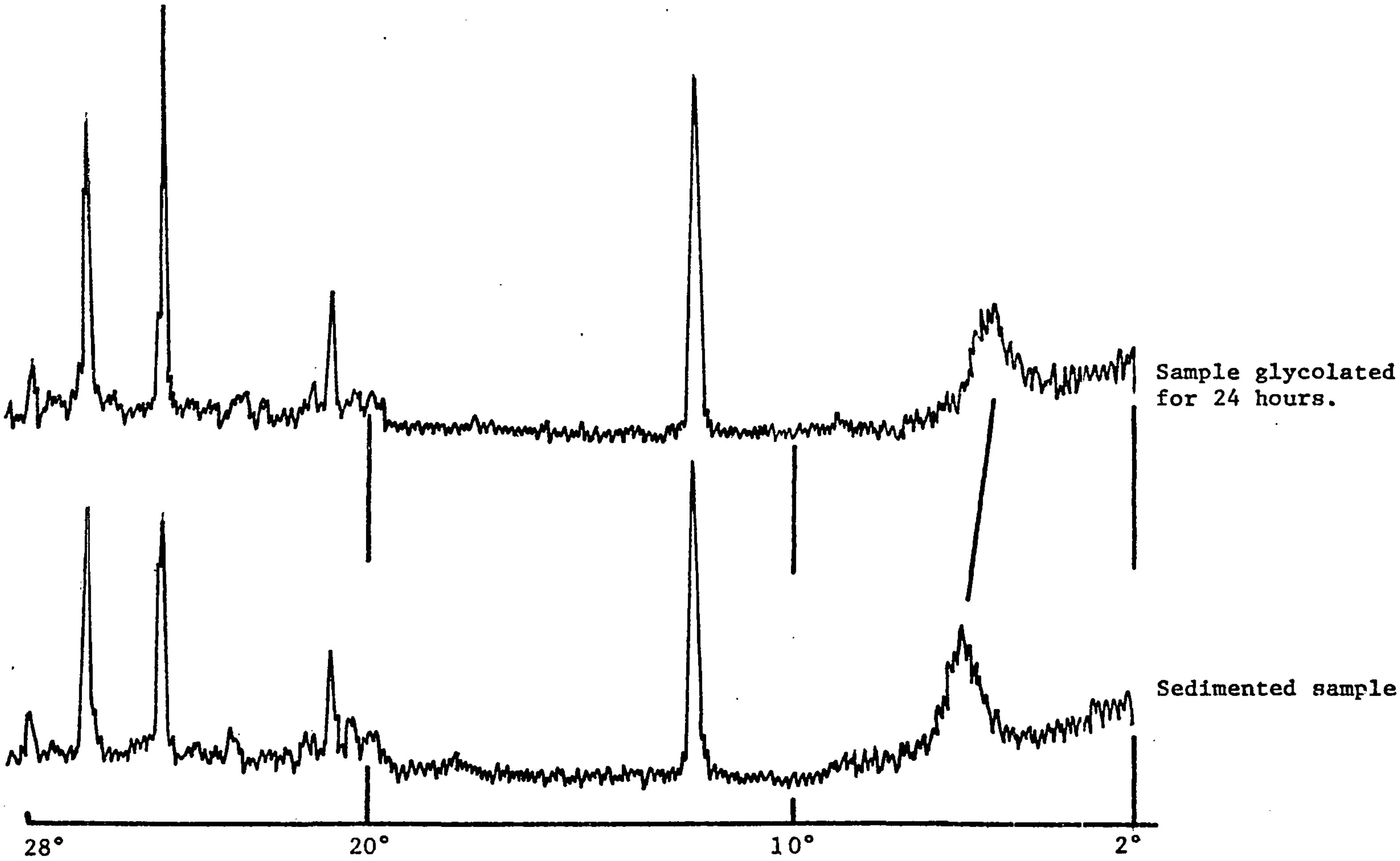
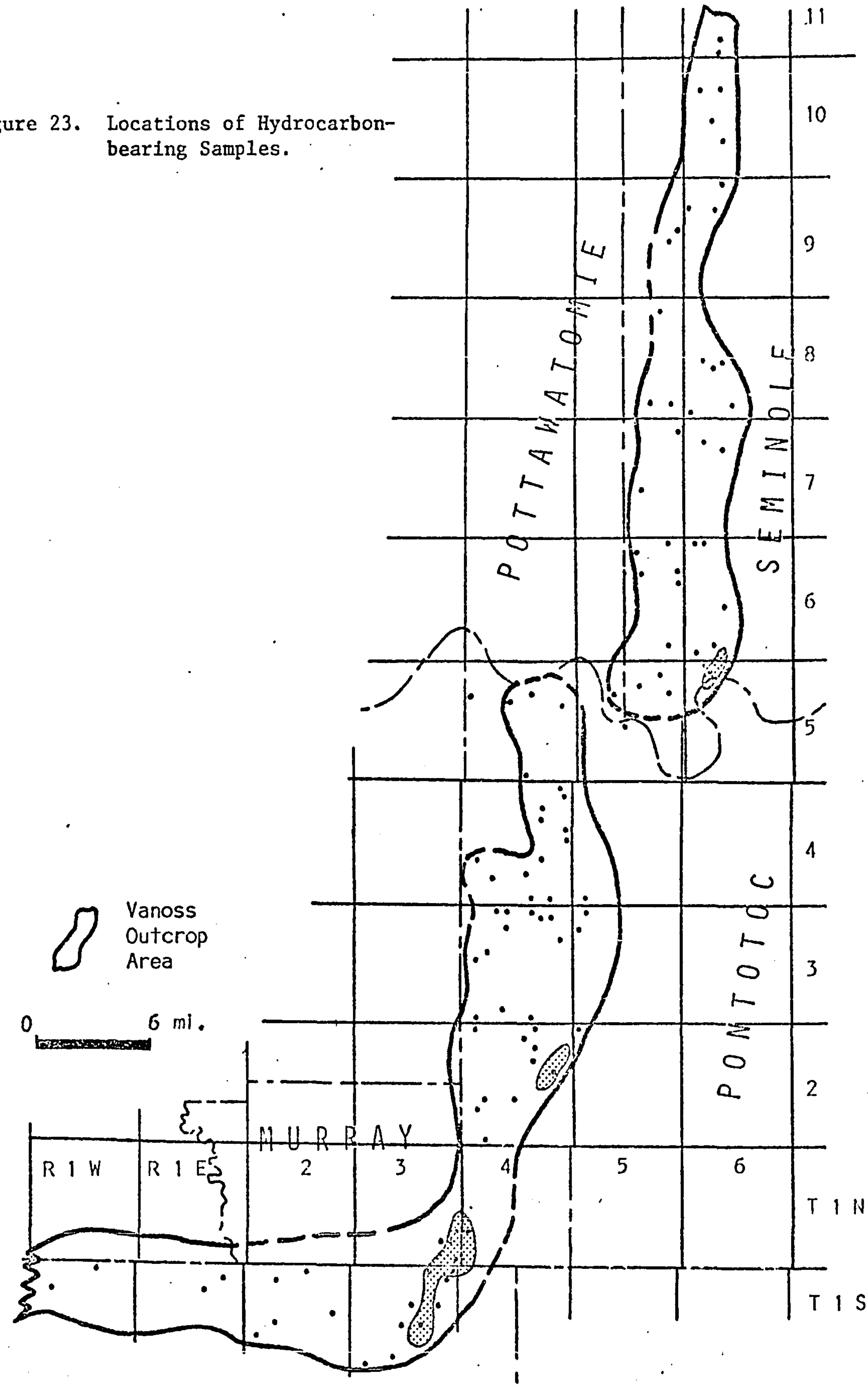


Figure 22. X-ray Diffraction Patterns of "Hydromica" collected from the center N 1/2, Sec. 16, T. 5 N., R. 4 E. Noticed is the 14Å peak shift with glycolation

Figure 23. Locations of Hydrocarbon-bearing Samples.



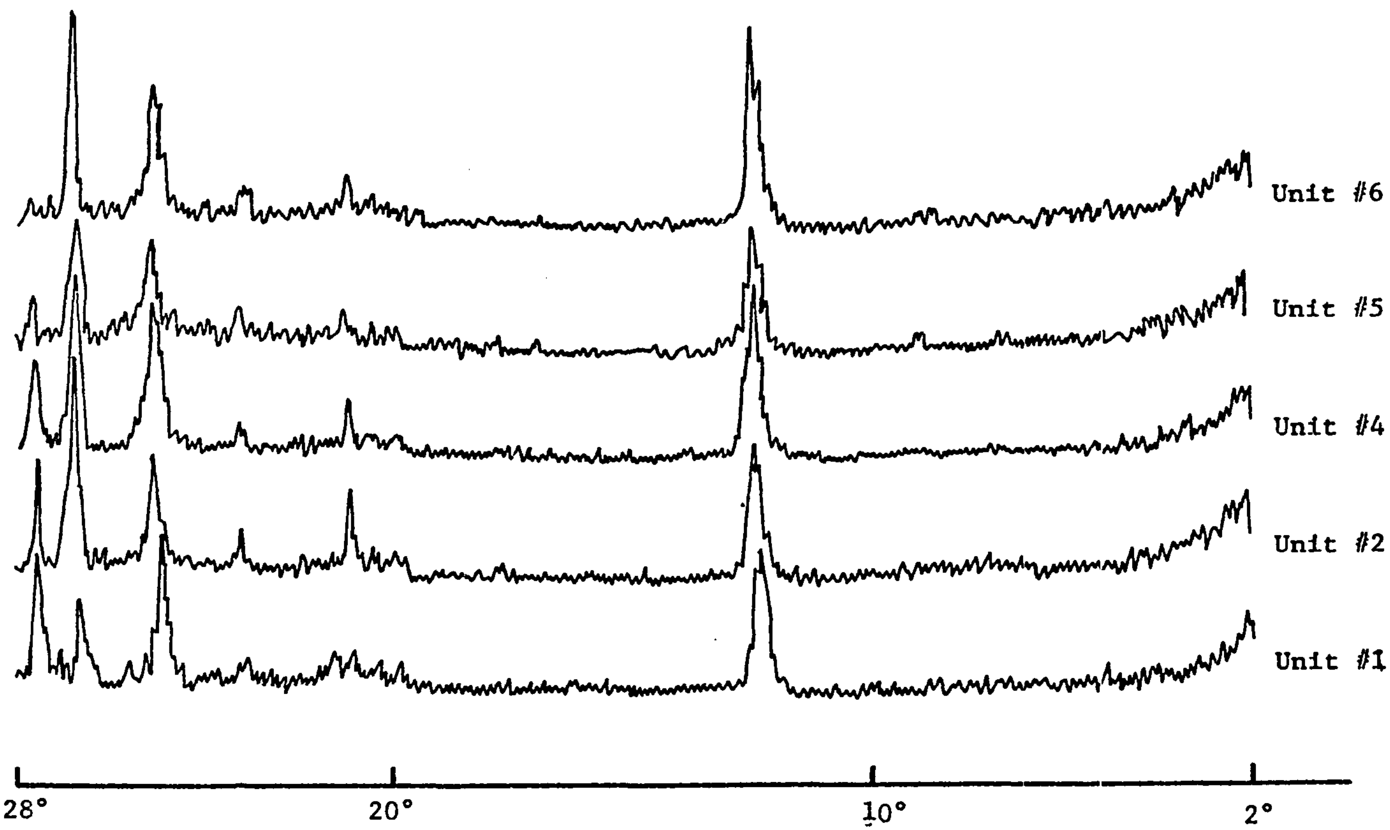


Figure 24. Variation of Clay Mineralogy in Sec. 30, T. 1 N., R. 4 E. Arranged in ascending order, samples show little variation.

obliterated by kaolinitization by circulating waters.

Associated Sand-Shale Pairs

A significant difference is present in clay mineralogy between sandstones and associated shales. While kaolinite is the dominant mineral in the sandstones, its relative abundance in proximal shales is diminished. Illite, montmorillonite and mixed-layer illite-montmorillonite are present in most shales but are not present in sandstone samples collected adjacent to the shales suggesting that diagenetic reconstruction has occurred in the sandstones. These data compare favorably to those of Bucke and Mankin (1971) who reported on clay mineral variations in sand-shale pairs sampled from cores of Desmoinesian age strata rather than from surface samples. Figure 25 shows the X-ray diffraction patterns for typical shales and associated sands.

Scanning Electron Microscopy

The sharpness of first and second-order basal peaks of kaolinite were unusual. In some samples, the (002) peak was more intense (higher) than the (001), but the third-order peak was generally weaker than that reported for dickite (Grim, 1969). Only one sample (X-ray sample # 19) yielded a clear-cut pattern for dickite out to $60^{\circ}\ 2\theta$; other samples were found to contain only exceptionally well-crystallized kaolinite.

In an attempt to understand why the kaolinite should exhibit such sharp peaks for low orders of basal reflections, two samples

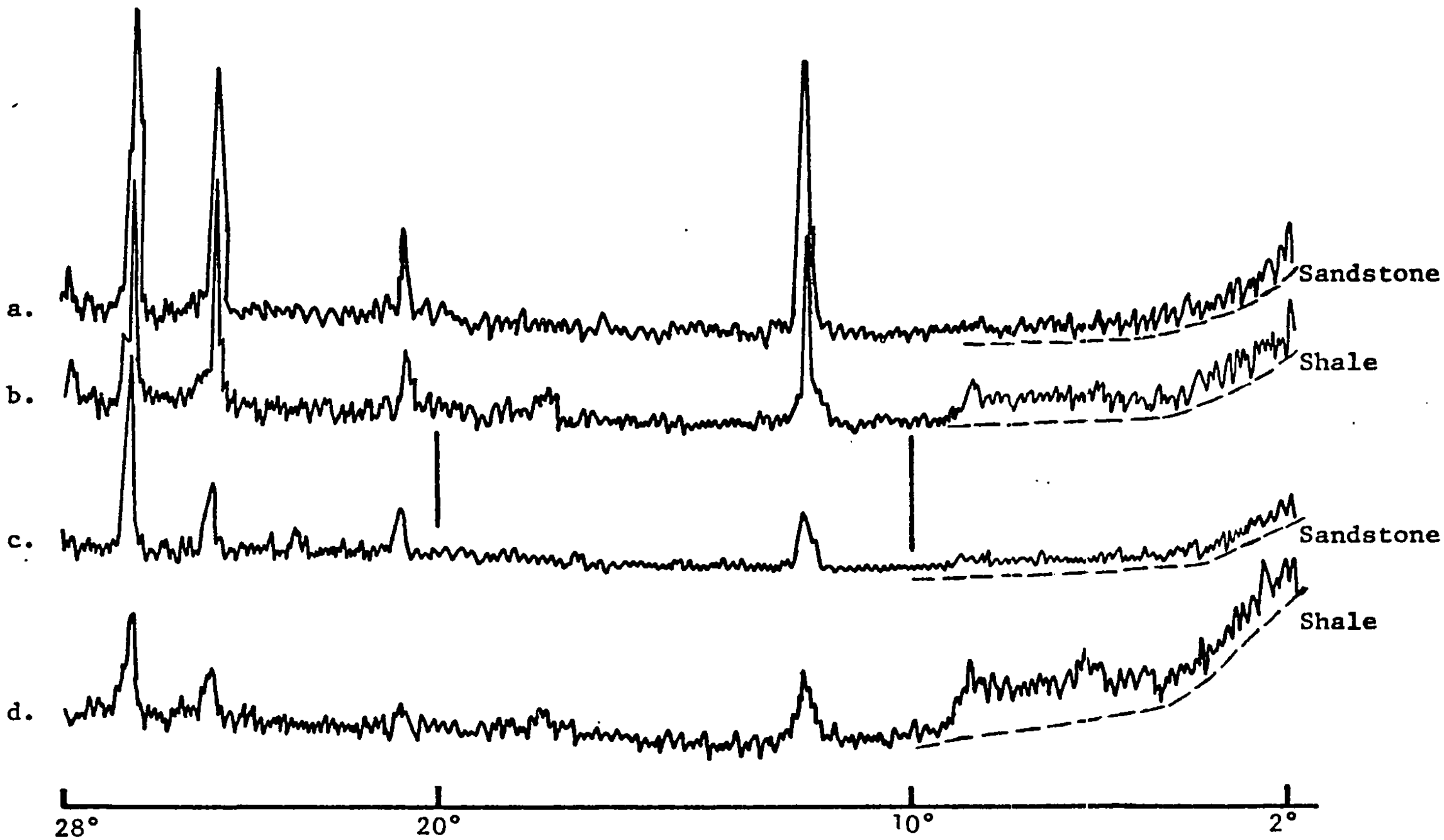


Figure 25. X-ray Diffraction Patterns of Associated Sandstone and Shale in the Vanoss
Samples (a) and (b) were collected from the SE 1/4, Sec. 2, T. 8 N., R. 5 E.
Samples (c) and (d) were collected from SW 1/4, Sec. 11, T. 4 N., R. 4 E.

(81 and 77) were compared by means of the scanning electron microscope and nondispersive analyzer. Exceptionally well-crystallized kaolinite as indicated by diffraction patterns, in sample 81 (Sec. 6, T. 6 N., R. 6 E.), proved to be a combination of two sizes of kaolinite; smaller crystals of kaolinite present on larger "detrital" kaolinite crystals. Use of the nondispersive analyzer revealed the two sizes of kaolinite to be nearly identical chemically; the authigenic guest crystals qualitatively contained slightly more iron.

Plate III displays scanning electron photomicrographs of kaolinite from two Vanoss sample localities; the well-crystallized sample (number 81), containing two sizes of crystals of kaolinite, and sample 77 (Sec. 30, T. 1 N., R. 4 E.), containing ragged "detrital" kaolinite as well as photos of kaolinite developed on "fresh" feldspar from the Century Granite Quarry and illite developed as cutan in some areas of the Formation. Locations of the samples are shown in Figure 26.

PLATE III

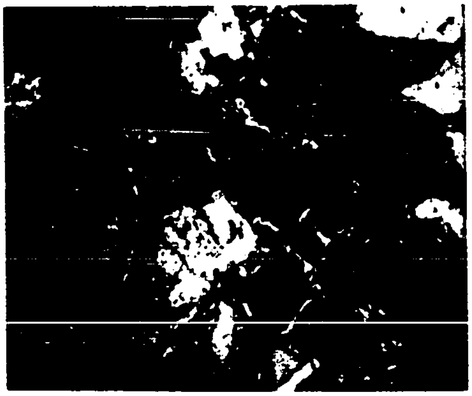
CLAY MINERAL TYPES OF THE VANOSS

A. Light colored cutan coating about subangular quartz, plagioclase, chert and opaque clasts. Cutan appears to be illite. Thin-section 6689, SE 1/4, Sec. 31, T. 4 N., R. 5 E.; crossed nicols, 35x.

B. Alteration of orthoclase crystal to kaolinite in "fresh" Troy granite; SW 1/4, Sec. 7, T. 2 S., R. 5 E.; thin-section 7057; crossed nicols, 35x.

C. Scanning electron photomicrograph of sample exhibiting ragged detrital kaolinite crystals; NW 1/4, Sec. 30, T. 1 N., R. 4 E., 5000x.

D. Scanning electron photomicrograph showing tiny crystals of kaolinite present on coarser kaolinite crystal; from NE 1/4, Sec. 6, T. 6 N., R. 6 E., 2500x.



A.

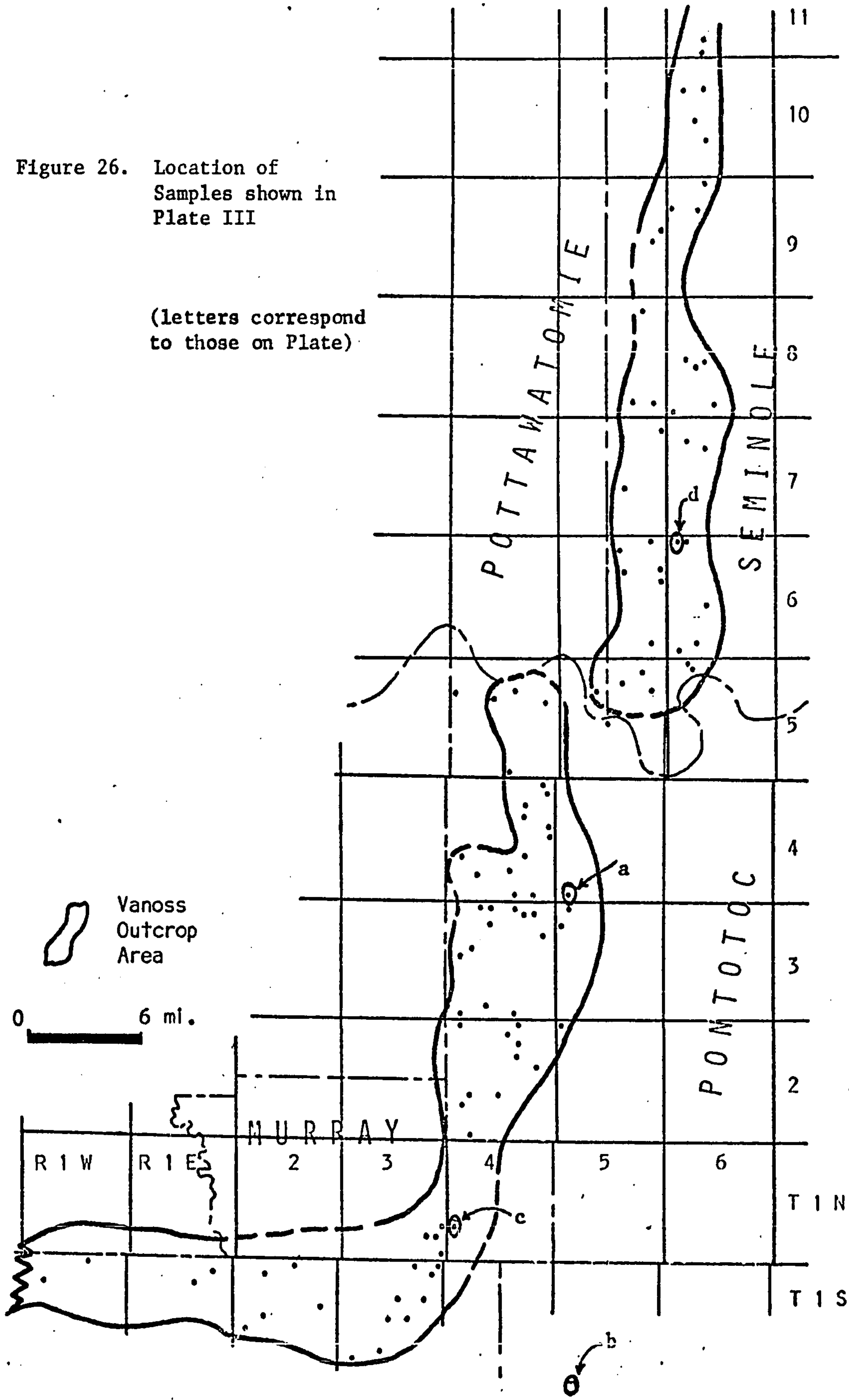
B.

C.

D.

Figure 26. Location of Samples shown in Plate III

(letters correspond to those on Plate)



HEAVY MINERAL ANALYSIS

All sizes of heavy minerals were examined: 16 minerals were identified from the thin-sections and grain mounts prepared for each of the samples collected for thin-sectioning; and 7 of the heavy mineral separations did not yield any heavy minerals. The mineralogy, grain size and shape of the heavy minerals in the Vanoss sandstones differed considerably from those in the shales. The total number of heavy mineral grains extracted was greater in shales than in sandstones and generally was of finer grain size and more euhedral. Zircon, for example, was more commonly subhedral or euhedral in shales than in sandstones. Blatt and Sutherland (1969) reported similar variations in nonopaque heavy minerals in sandstone-shale pairs in the Tertiary of Texas. They explained the difference as a result of intrastratal solution of heavy minerals in the permeable sandstones.

Reported analyses of the accessory minerals of the Tishomingo and Troy granites (e.g., Uhl, 1932) show that trace amounts of subhedral and euhedral crystals of the following occur: zircon, ilmenite, rutile, tourmaline, sphene, garnet, apatite, epidote, topaz and magnetite. Biotite and hornblende are more common accessory minerals than those listed above but as shown earlier (see Table 1) Ham, Denison and Merritt (1964) report they are most common in the diorite portion or the biotite-hornblende zenoliths of the Troy granite.

Table 4 lists the heavy minerals identified, of which the majority are nonopaque (58 per cent). Approximately two grains in five were opaque minerals and unidentifiable minerals comprised about 4.3 per cent of the total. The "unknown" category included grains coated with clay or iron and were unidentifiable or those where identification was uncertain because of heavily abraded surfaces or uncertain optical character.

The zircon-tourmaline-rutile ultrastable group of heavies makes up 72 per cent of the nonopaque fraction. Folk (1968, p. 97) indicates that predominance of the Z-T-R suite in sedimentary rocks means that they were derived from previous sedimentary rocks and have undergone extensive abrasion or extensive chemical attack.

Heavy minerals were not abundant in limestone or limestone conglomerate of the Vanoss. The most common heavy minerals were epidote, apatite, zircon and garnet. Occasionally magnetite was present as highly altered, rounded grains.

The normal interpretation of a heavy mineral suite as shown in Table 4 would suggest a source rock which was sedimentary and metamorphic in nature. The high concentration of zircon + tourmaline + rutile indicates an older sedimentary rock source but Uhl (1932) has shown that these three minerals are present in the known plutonic source (Folk, 1968, p. 98); the garnet (8.6 per cent) could be igneous, sedimentary or metamorphic with the latter most likely. All of the other heavy minerals occur in such small amounts that their presence would not in itself constitute a strong indication of particular types

TABLE 4

HEAVY MINERALS OF THE VANOSS FORMATION

Mineral[a]	Number of Grains	Total (%)	Nonopaque (%)
Zircon	4,699	40.0	56.8
Magnetite	1,257	10.7	. .
Hematite	1,124	9.6	. .
Garnet	1,005	8.6	12.2
Ilmenite	887	7.6	. .
Tourmaline	737	6.3	8.9
Rutile	531	4.5	6.4
Unknowns	505	4.3	6.1
Epidote	286	2.4	3.5
Hornblende	214	1.8	2.6
Apatite	214	1.8	2.6
Pyrite	206	1.7	. .
Anatase	49	0.4	0.6
Sphene	23	0.2	0.3
Spinel	4	0.03	0.04
Andalusite-Staurolite	4	0.03	0.04
Totals	11,745	100.00	100.00

[a]Zircon-Tourmaline-Rutile (stable heavies)= 70.5 per cent of nonopaques. Opaque Minerals (Magnetite, Ilmenite, Hematite, Pyrite)= 29.6 per cent of total heavy mineral suite.

of source rock.

Grain shape for all heavy minerals in the Vanoss Formation, whether for a single variety or for the entire suite, was not correlative with distance of transport. Such changes in grain shape, therefore, are a function of postdepositional alteration of the heavy mineral suite due to circulating pore waters.

Distribution of Heavy Minerals

Distribution maps showing per cent concentrations of various minerals as a portion of the total heavy mineral suite show, in some cases, patterns which may be related to source areas indicated by other mineralogic data (e.g., microcline-perthite distribution). Selective removal of certain heavy minerals by chemical action and the presence of heavies derived from both igneous and sedimentary source rocks alter possible depositional patterns.

The distribution maps showing ultrastable (zircon, tourmaline and rutile) minerals (see figs. 27, 28 and 29) show no diagnostic trends though rutile is concentrated in T. 3 N., R. 4-6 E., the same region where higher concentrations of feldspar were noted. Photomicrographs of heavy minerals from shales and sandstones show that zircon, tourmaline and rutile grains are coarser and better rounded in sandstones (see Plate IV). Each of these minerals increases in abundance northward because of either removal of less stable heavies by solution during diagenesis or an increasing distance from the source areas.

Apatite also is common in the Vanoss with maximum concentration in the region where limestone conglomerate is the common rock

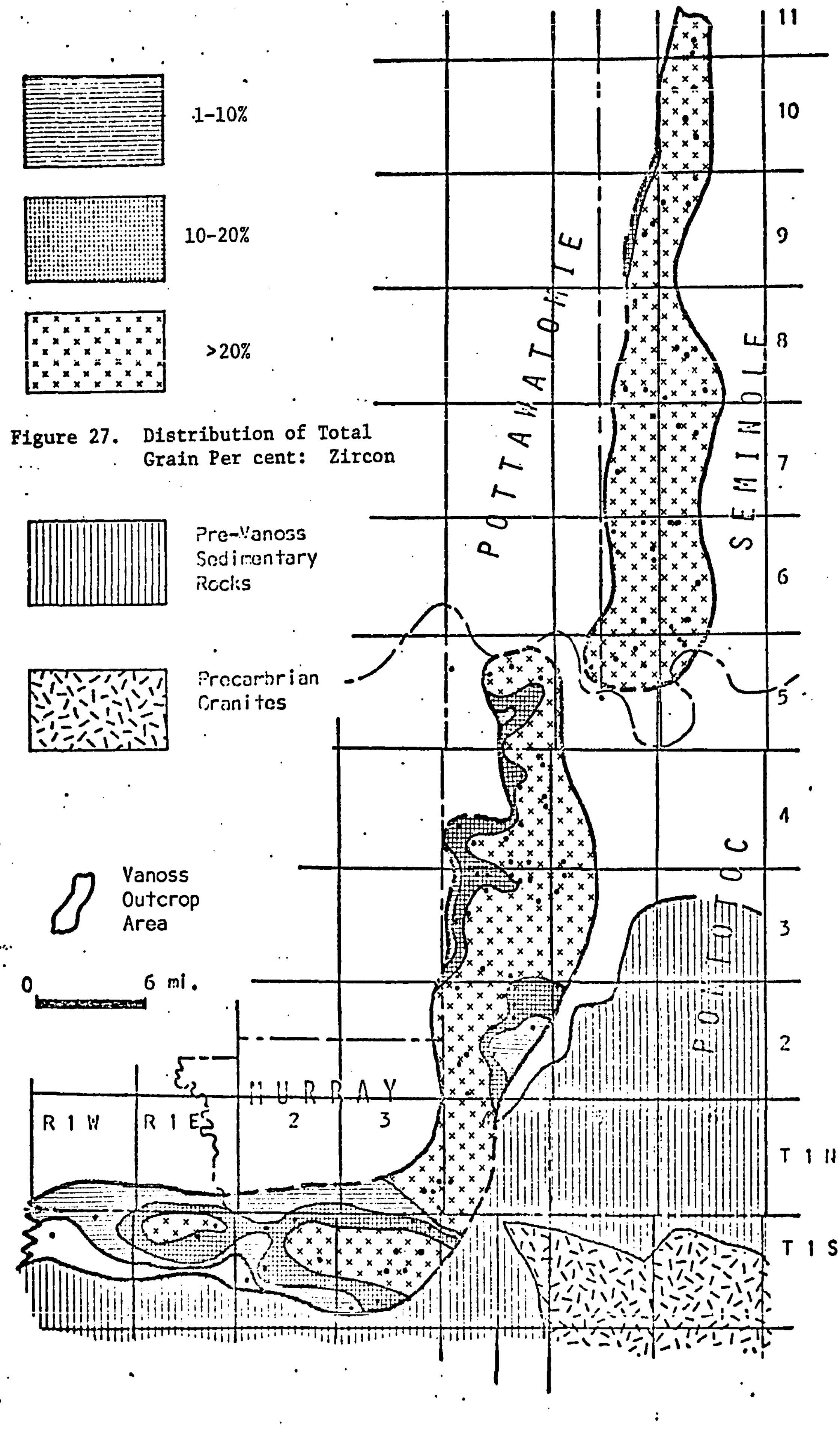


Figure 27. Distribution of Total Grain Per cent: Zircon

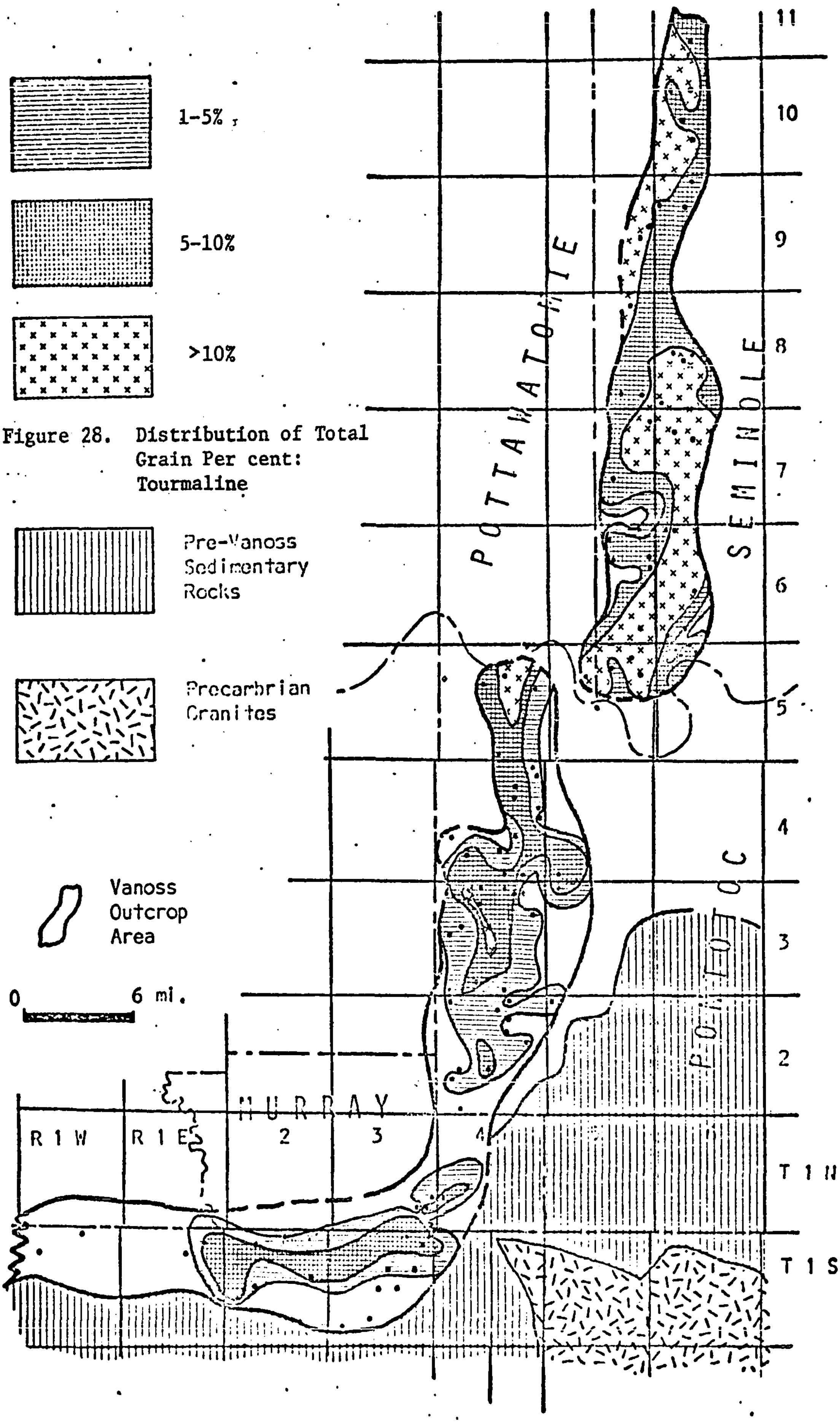


Figure 28. Distribution of Total Grain Per cent: Tourmaline

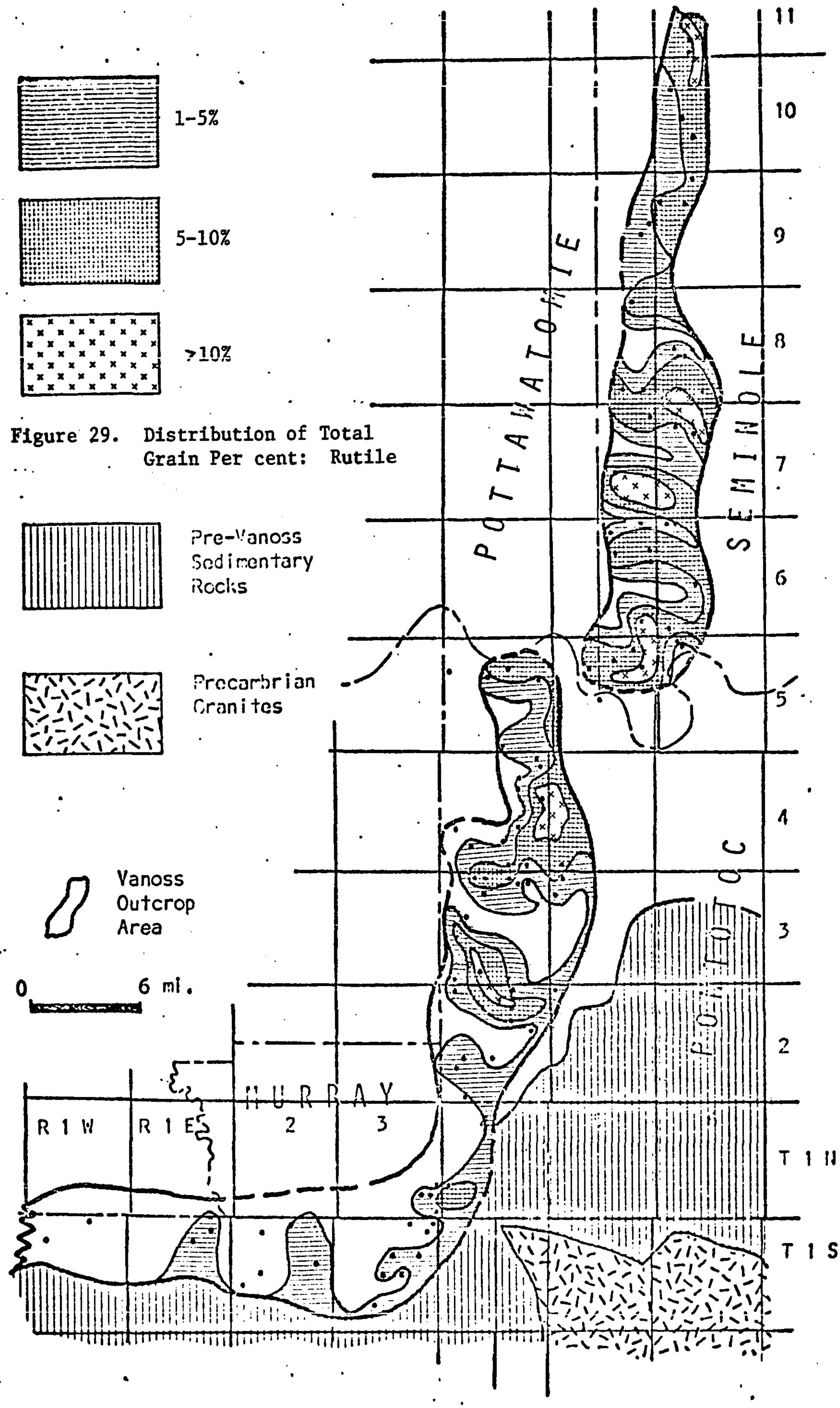


Figure 29. Distribution of Total Grain Per cent: Rutile

type (see fig. 30); and the presence of apatite with the large clasts of limestone attest to a sedimentary source for some of the apatite. Again, Uhl (1932) has indicated the widespread occurrence of apatite in trace amounts within the granites of the Arbuckle Mountains.

Biotite, though common in thin-sections of the Vanoss, was irregularly present in heavy mineral separations owing to its specific gravity (2.80 to 3.2) which straddles the density of the heavy liquid employed in density separation (tetrabromoethane, density 2.95). Present in Vanoss thin-sections were pale green and brown biotite grains as well as fresher-appearing brown particles identical to the biotite observed in thin-sections of the source granites. Folk (1968, p. 87) notes biotite is a common accessory in granites and its presence in sands is due to either erosion at a rate greater than weathering of granitic source rock or a volcanic source. I have noted an absence of biotite in thin-sections of Lower Paleozoic sedimentary source rocks and assume that the pale varieties of biotite formed by leaching iron (ferric) from the igneous biotite. Figure 31 shows the concentration of biotite highest in the middle portion (T. 3 N., R. 4-5 E.) where other igneous components were most common.

Garnet was rather widespread, occurring in all lithologies of the Vanoss Formation (see fig. 32). Grain size ranged approximately between 0.8 Ø and 4 Ø, with the finer grains more common in shales and larger grains being more common in the limestone conglomerates of T. 1 S. and T. 1 N. Coarser grains were more commonly abraded and were doubtless derived from the older Paleozoic sedimentary rocks; e.g., the carbonates and sandstones of the Simpson (Ordovician) Group which locally

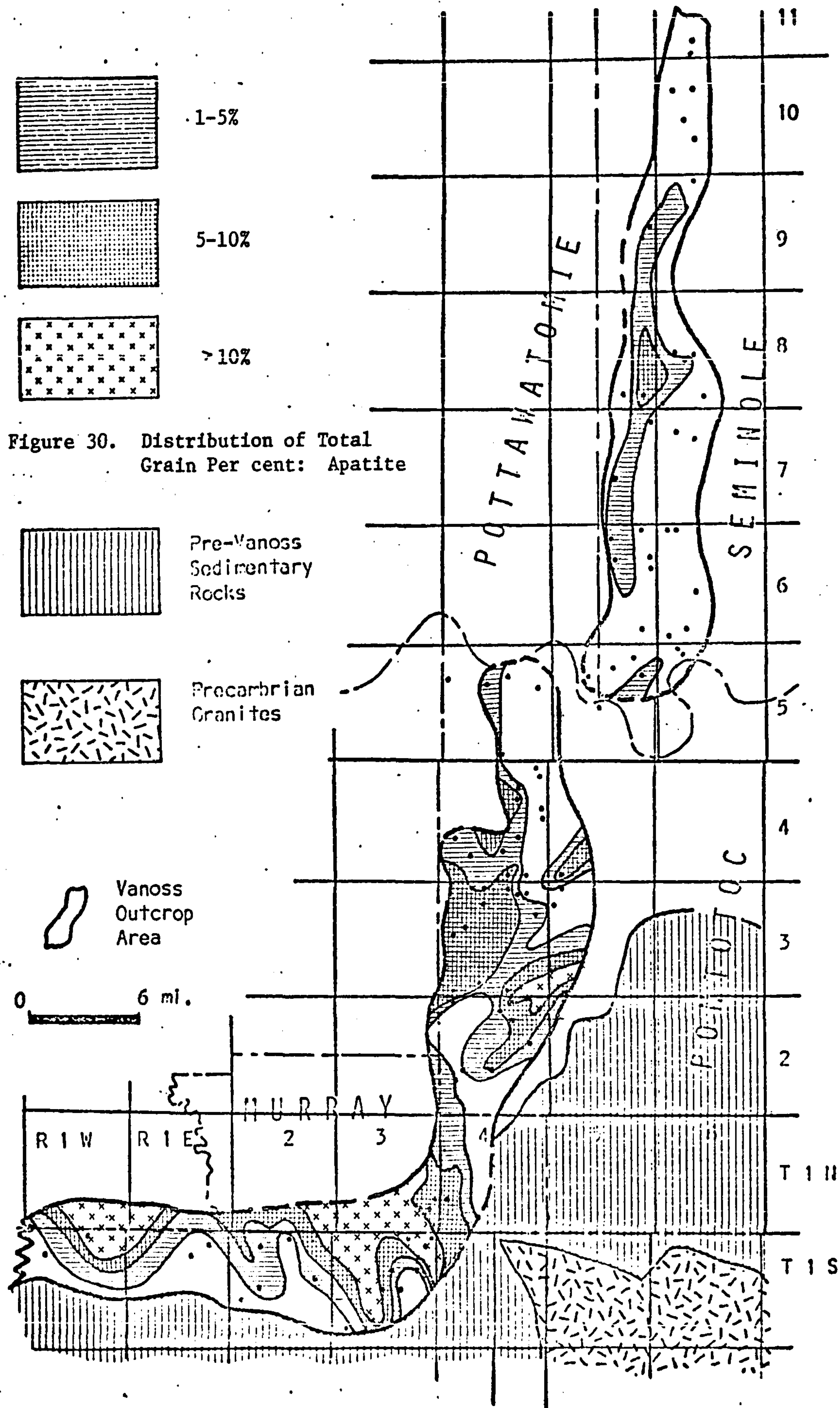


Figure 30. Distribution of Total Grain Per cent: Apatite

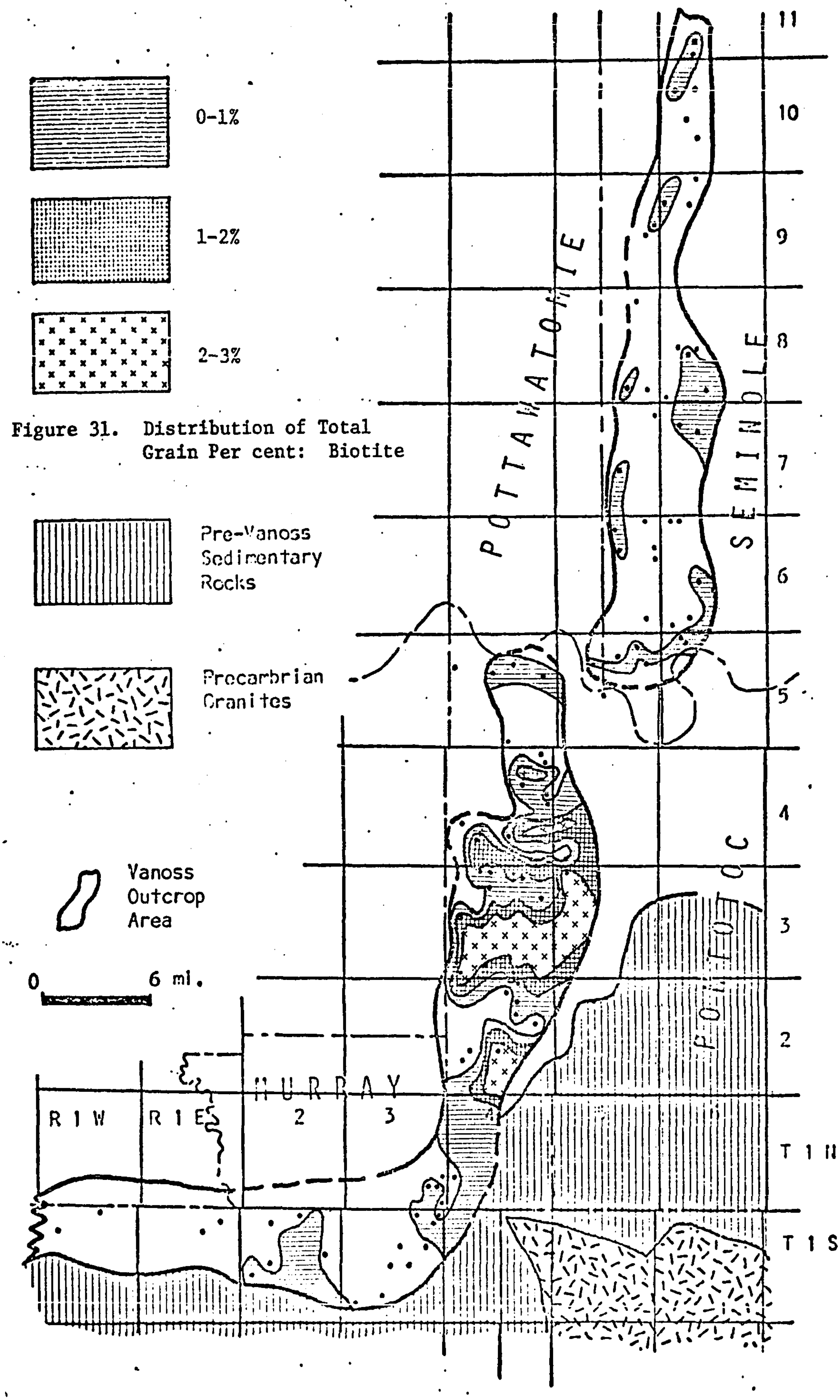


Figure 31. Distribution of Total Grain Per cent: Biotite

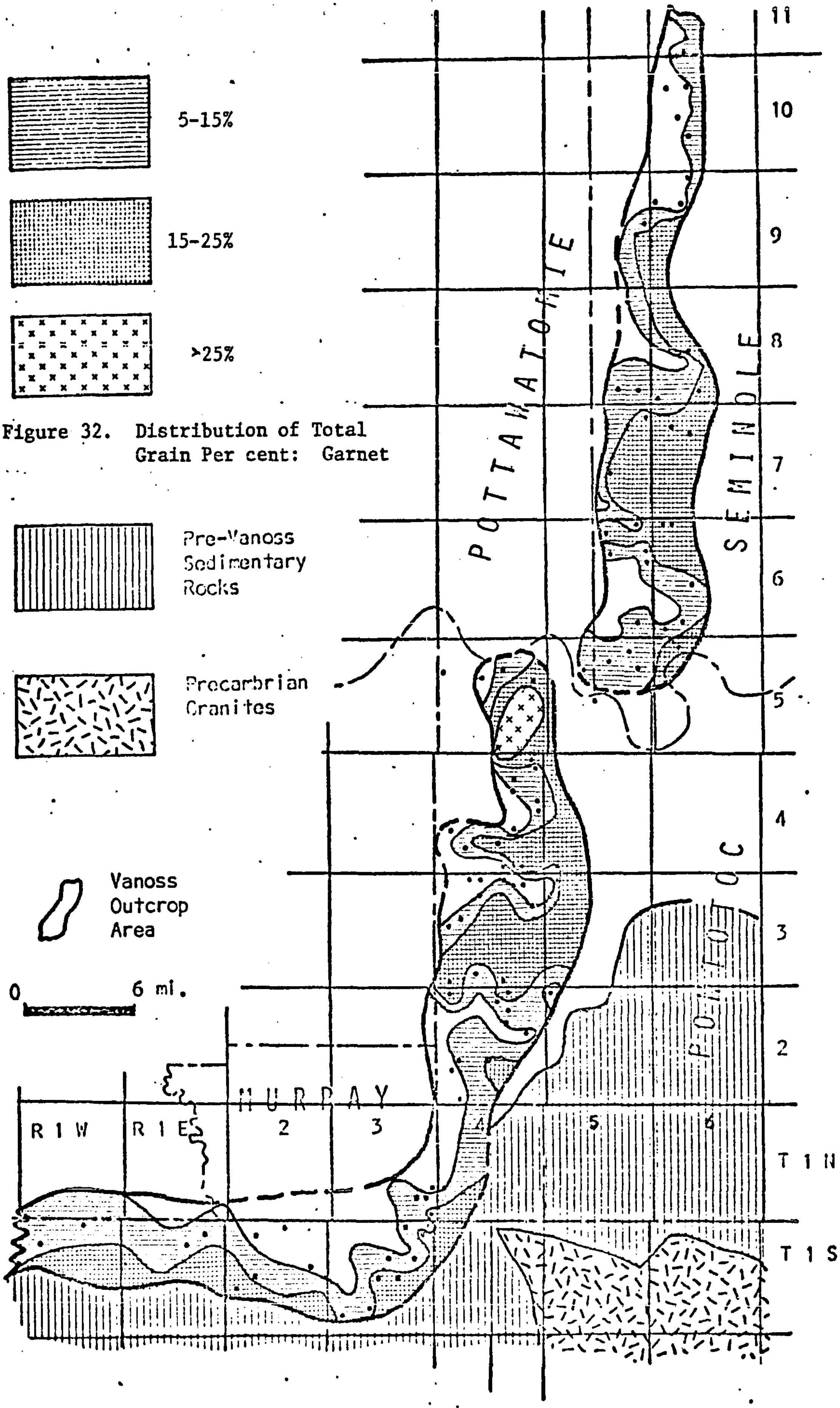


Figure 32. Distribution of Total Grain Per cent: Garnet

contain garnet.

Colors of garnets ranged from pale red to colorless. In the granites, the writer has observed very few garnets (all pale red). Ham, Denison and Merritt (1964, p. 135) ascribe their presence to deuteric alteration of the Eastern Arbuckle Province rocks. At least a portion of the maximum concentration of garnet in T. 5 N., R. 4 E. can be tied to a nearby igneous source to the east or southeast, especially recalling that other indicators of igneous source rock also suggest an eastern source area in that vicinity.

Magnetite, too, was broadly distributed (see fig. 33) within the Vanoss but in concentrations generally less than 1 per cent (1 grain per 300 grains as an average) in thin-sections. Most grains were coated with iron-stained clay or were in various degrees of alteration to hematite. Grain size of magnetite in the grus was about 2.0 Ø and only slightly less than 2.4 Ø in the sandstones, the lithology with which magnetite was most commonly associated. Coarser grains of magnetite clumped in the western portion of T. 4 N., R. 5 E. and appeared (subjectively) less highly altered than those to the north. Since most of the grains were subhedral, magnetite is of little value in determining directions of transport.

Hornblende, derived from the diorite phase of the Troy granite or from hornblende-biotite zenoliths in the Troy, is virtually absent from samples south of T. 3 N., R. 4-5 E. (see fig. 34). The lone exception is in the sandstones of the gravel pit in Sec. 30, T. 1 N., R. 4 E. Unfortunately, the abundance of hornblende is too slight to indicate much about the distribution pattern other than hornblende is

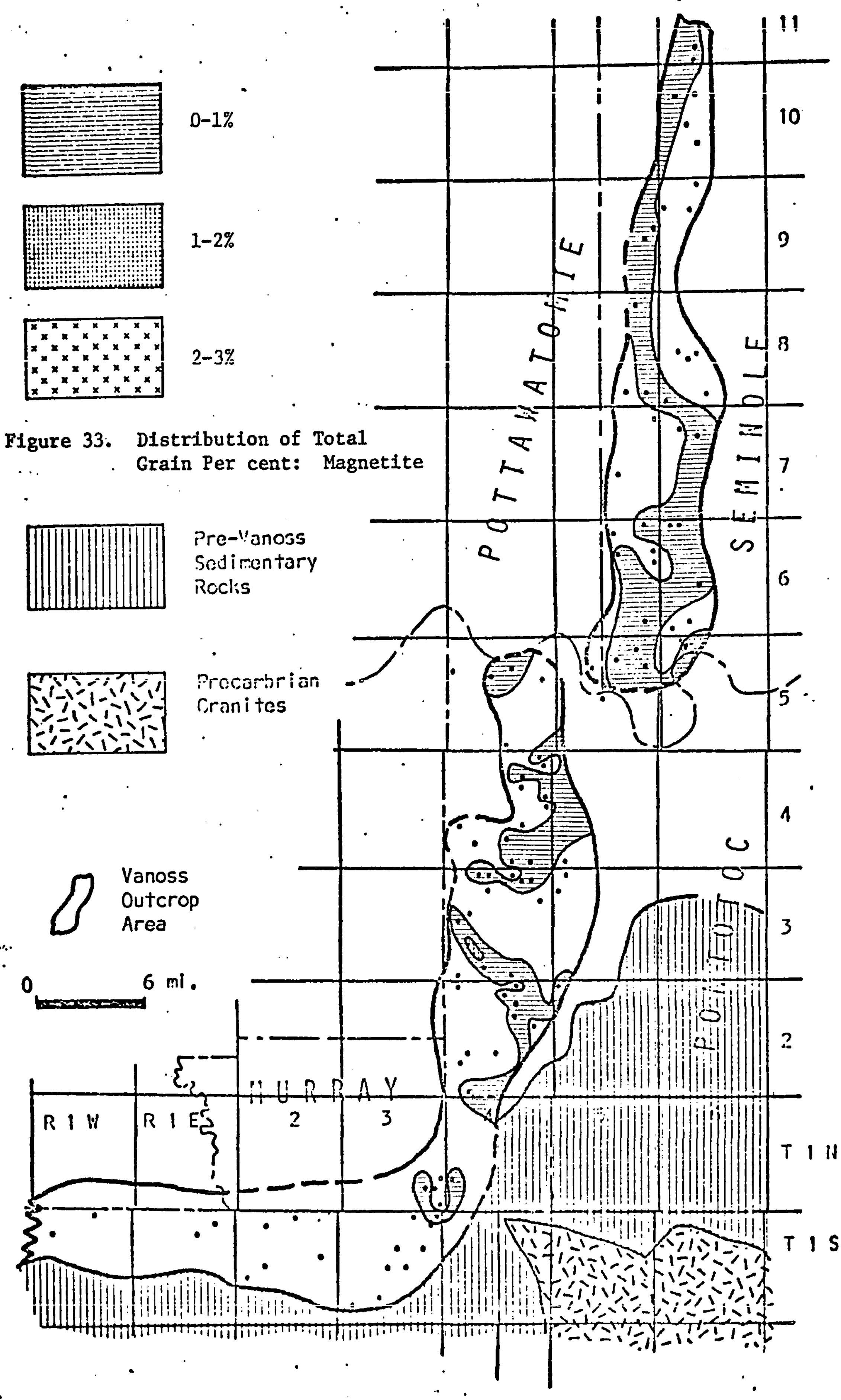


Figure 33. Distribution of Total Grain Per cent: Magnetite

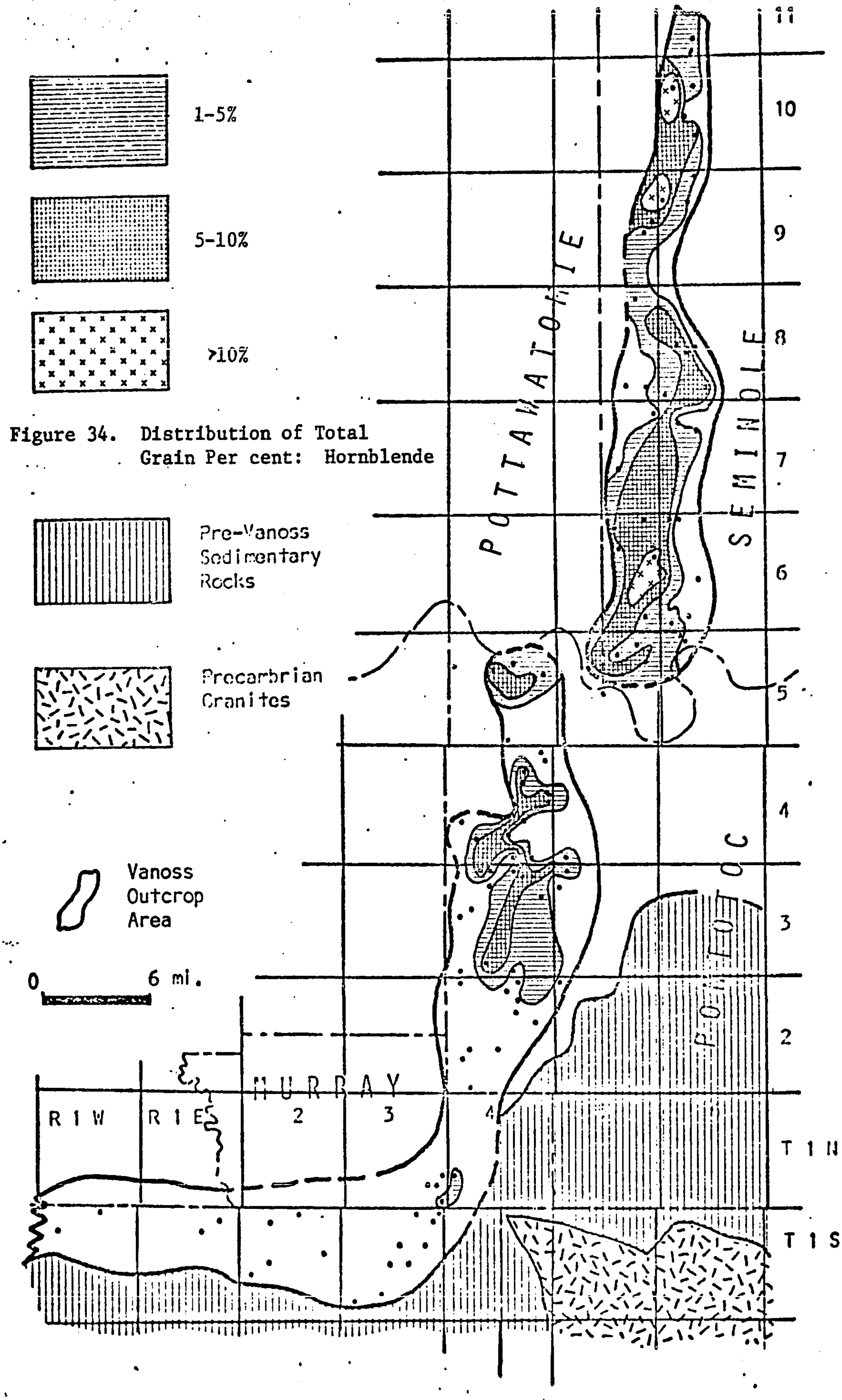


Figure 34. Distribution of Total Grain Per cent: Hornblende

still present at least 36 miles north of T. 3 N., as anhedral grains about 3.0 Ø in size. Original hornblende grain size in thin-sections of Troy granite averages 1.0 Ø.

It was hoped that the mineralogy of the hornblende group could be determined but optic signs were obtainable on only four grains; each being monoclinic (?), biaxial negative and having indices of about 1.71. According to Deer, Howie and Zussman (1963, p. 265) hornblende of this character is probably ferrohastingsite which occurs in alkali granites and in granite pegmatites. They also point out (p. 295) that nothing short of a complete chemical analysis will reveal the true chemistry of hornblendes.

Distribution maps for other detrital heavy minerals were attempted but the results were even less satisfactory. Epidote is an example; present in both granitic and sedimentary source rocks of the Vanoss, it is widespread but is absent in limestone conglomerates (see fig. 35). Grains were typically subrounded and 1.5 to 2.0 Ø in size throughout the outcrop area. No concentrations related to either an eastern or southern source are apparent.

Similar maps were attempted for hematite, spinel, zoisite (?), and fluorite. None showed patterns of concentration though hematite was widespread and common in all lithologies of the Vanoss Formation.

Two authigenic heavy minerals, anatase and pyrite, were also found. More restricted in their areas of occurrence than the detrital minerals, they were generally euhedral to subhedral and occurred in rocks containing less calcite cement than associated rocks of equivalent grain size (see figs. 36 and 37)--probably due to differing permeability.

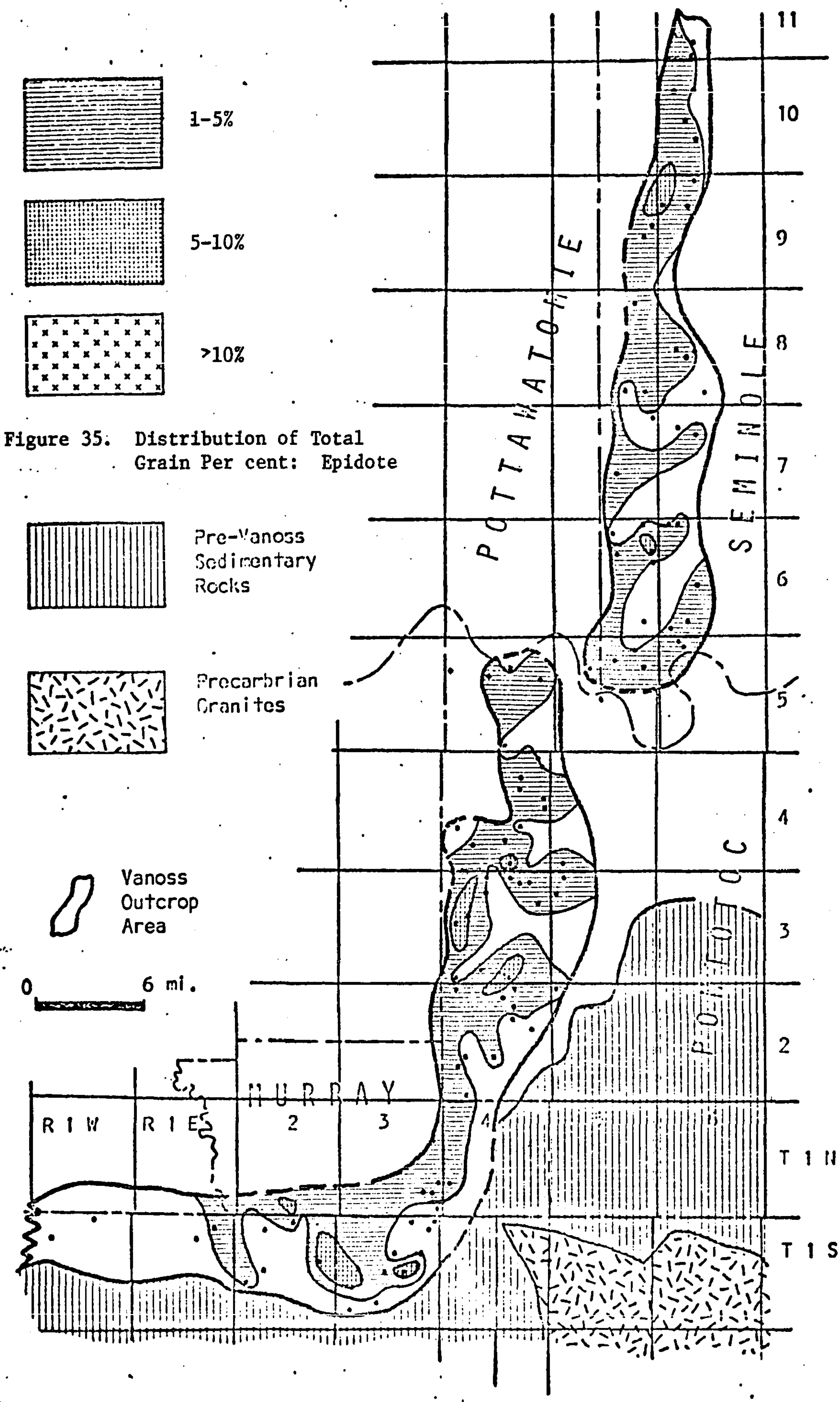


Figure 35: Distribution of Total Grain Per cent: Epidote

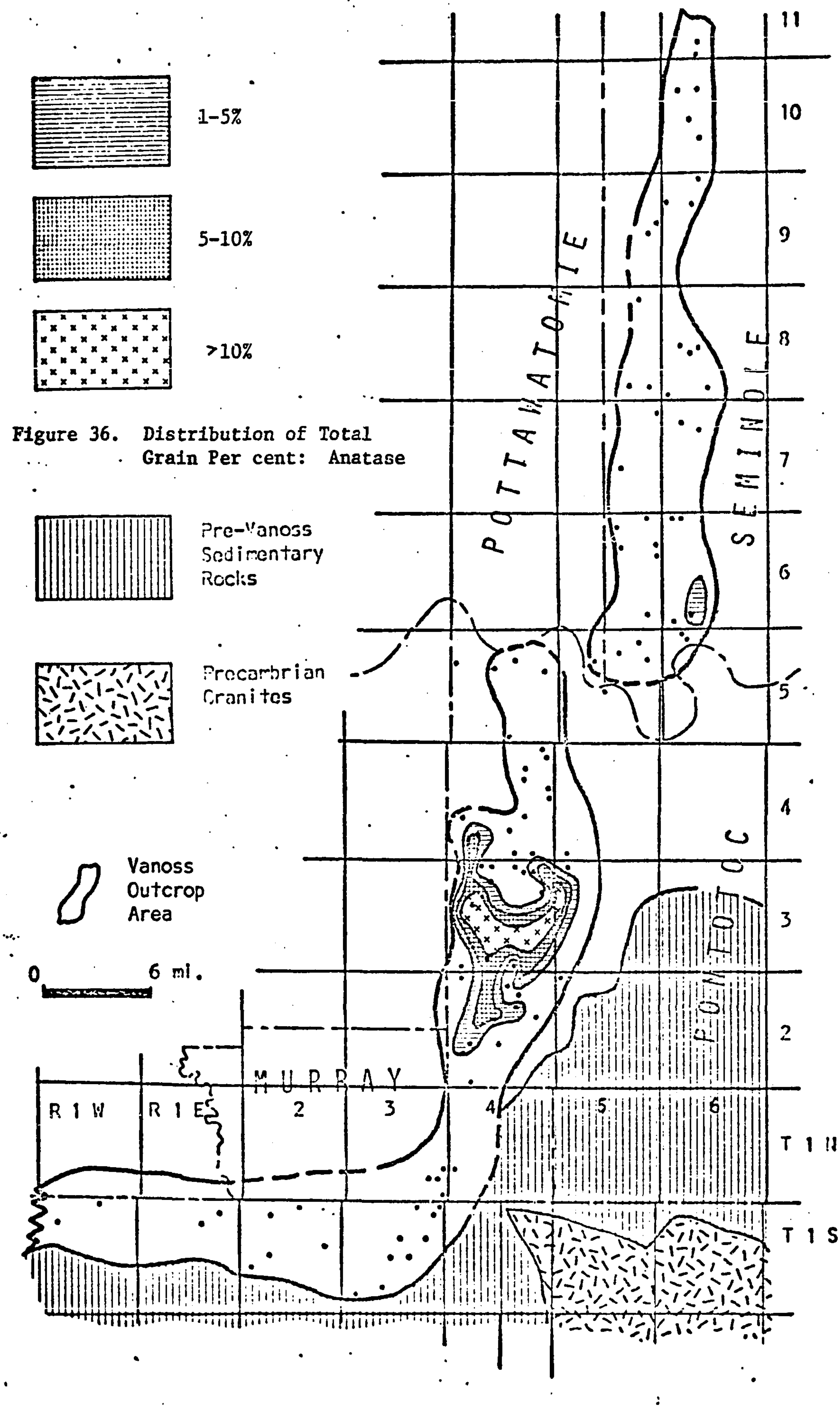


Figure 36. Distribution of Total Grain Per cent: Anatase

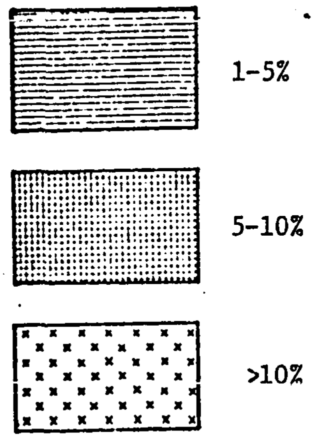
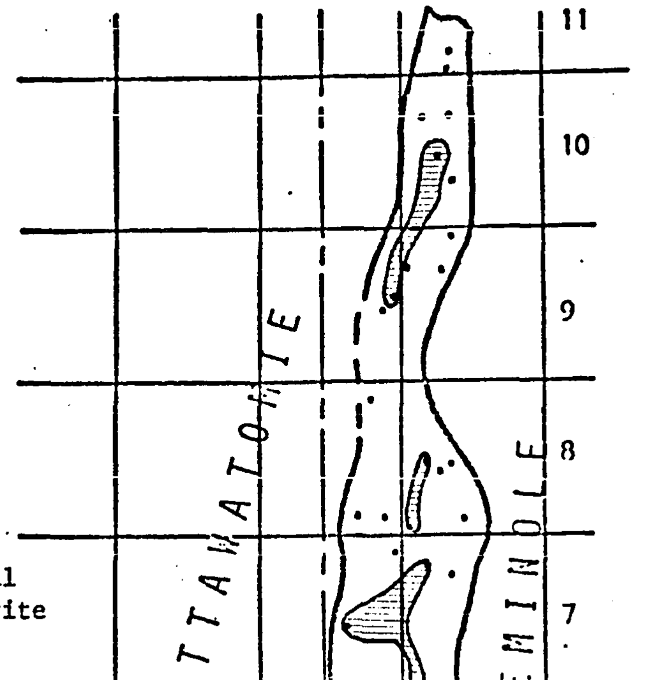
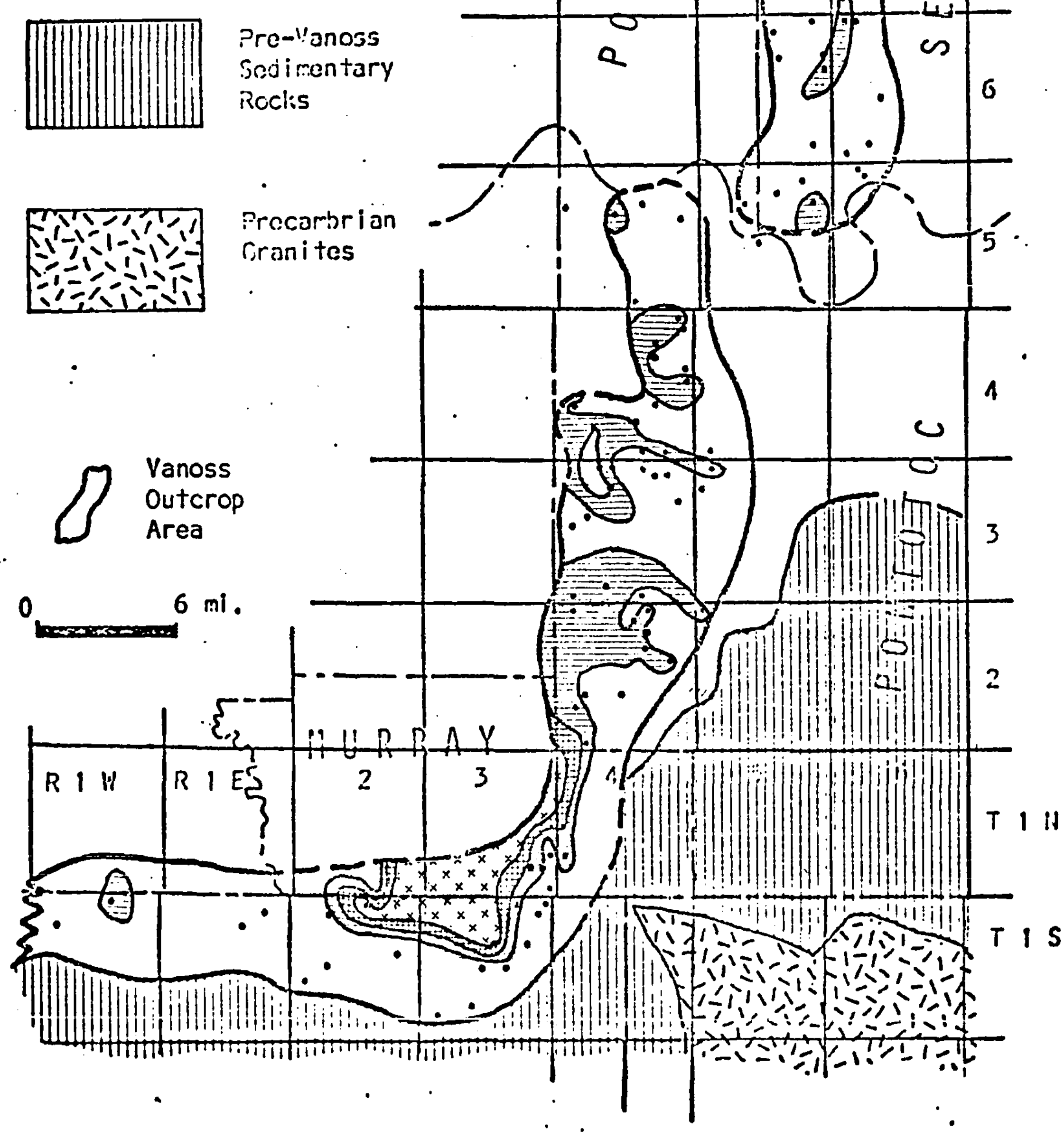


Figure 37. Distribution of Total Grain Per cent: Pyrite





The only crystal forms observed of pyrite were cubes or octahedra ranging in size between 2 Ø and 4 Ø. Diagenetic pyrite forms in shallow water where Eh is negative and pH less than 7.0 (Krumbein and Garrels, 1952). Deer, Howie and Zussman (1963, p. 140) report that sedimentary pyrite of authigenic origin is generally poorly crystallized as cubes or octahedra.

Anatase crystals were found in one large area. Crystals were typically elongate uniaxial negative tetragonal prisms or pyramids. Mean grain size was 2.6 Ø and indices of refraction were about 2.52 and 1.43. Some grains were weakly pleochroic, varying among pale shades of blue, brown, or green. Many crystals exhibited geometric zoning.

Deer, Howie and Zussman (1963, p. 42) and others agree that anatase is a low-temperature form of titanium dioxide which alters from Ti-rich minerals such as ilmenite or sphene. Comparisons were made between distribution maps of the various Ti-rich minerals encountered, and only the abundance of rutile showed any relationship to anatase distribution. It may be seen by comparison of distributions that where rutile concentration was low, anatase was in high concentration. This suggests that anatase alters from rutile under proper (but undetermined) conditions and that it is not directly related to other parameters used to characterize the Vanoss Formation. Whereas the pyrite concentration suggests swampy conditions on the floodplain portion of the Vanoss outcrop area, the presence of anatase indicates little about the paleoenvironment. Authigenic formation of heavy minerals (anatase and pyrite) plus the local siderite cement occurrences suggest further that bacterial decay locally depressed the Eh and perhaps initially formed from hydrotroilite ($Fe_2O_3 \cdot nH_2O$) as Bucke and Mankin (1971, p. 978) have indicated.

SUMMARY AND CONCLUSIONS

Results of this study may be grouped into two categories:

1. mineralogic and petrologic data providing information about dispersal patterns within the Vanoss Formation north of the Arbuckle Mountains; and
2. the relative merits of the light mineral, heavy mineral and clay mineral fractions of clastic wedge deposits as exemplified by the Vanoss Formation.

A Stratigraphic Model of the Vanoss

Prior to this study the geologic history of the Vanoss was based on work primarily by Ham, Dunham and Morgan (proximal to the source area) and Tanner (in the Seminole County area, further to the north). Their approach was largely stratigraphic and suggested a rather straight-forward model as briefly summarized below.

1. As the Arbuckle "welt" flexed upward along a general E-W axis, coarse detritus from the uplifted lower Paleozoic sedimentary rocks were shed toward the north, south and west. (Note: Since this study deals with the Vanoss exposed north of the mountains, the remaining points apply specifically to that area.)

2. As a function of stream transport, grain size diminished northward away from the mountain front and the high gradient streams could transport the coarsest cobbles only short distances. Lateral variations in grain size along depositional strike were due to varying stream gradients, rock types and degree of uplift. Dunham (1955) reported the largest cobbles to be present at the western end of the mountains.
3. The continued unroofing exposed the Precambrian plutonic core area to erosion and granitic detritus was added to the clastic wedge and extended a greater distance from the front. This assumes that the core was uplifted south of the mountain front, in the area where granite is exposed today.
4. The final stage of deposition was an upper shale member, occasionally feldspar-bearing. Streams depositing this lithology must have been flowing across broad alluvial plains.
5. North of Seminole County beyond the study area, the Vanoss and underlying Ada Formations have not been mapped separately because they aren't lithologically distinct (shales and interbedded sandstones). Probable mixing and reworking by coastal currents (presumably) of sediments from southern (Arbuckle Mountains) and eastern Ouachita Mountains ?) sources caused the lithologic similarity.

Mineralogic-Petrologic Patterns of the Vanoss

The model of Ham, Dunham and others is generally correct but the present work reveals mineralogic variations that require a significantly different sediment dispersal pattern from the simple model proposed by those workers.

There were two primary source areas for detritus in the Vanoss Formation north of the Arbuckle Mountains; one a sedimentary source south of the western portion of the present Vanoss outcrop belt (e.g., T. 2-3 S.), and an igneous source east-southeast of the exposed Vanoss (T. 3-4 N., R. 5-6 E.) in the northern part of Poutotoc County. Lesser amounts of sedimentary and igneous detritus were shed from an area between the two principal sources (see fig. 38).

Mineralogic variables which support the igneous and sedimentary sources are summarized below (note appropriate maps in previous text):

1. Sedimentary source (T. 2-3 S.); distribution of limestone clasts, chert clasts and concentration of overgrown quartz grains.
2. Igneous source (T. 3-4 N.); distribution of perthite, total feldspar, granite rock fragments, polycrystalline quartz and the maximum grain sizes of quartz. Indications less diagnostic are given from distribution of hornblende, rutile and magnetite.

The western (sedimentary) source must have been quite close to present exposures of conglomerate in T. 1 S., R. 1 W. and R. 1 E. because the large limestone cobbles are well-rounded and are not present in the Vanoss less than 30 miles north in the Vanoss. Quartz grains present are commonly overgrown and must have come from the numerous sandstone units in the Ordovician Simpson Group.

The highest concentration of igneous-derived material is in T. 3-4 N., R. 4-5 E. Most of the coarse detritus is gone within 18 miles of this maximum concentration area. This is unusual because the nearest present-day granite exposure is in Johnston County, 24 miles to the south.

Cementation variations in the Vanoss are explained by the varying chemistry of circulating waters. Along the entire mountain front where abrasion of coarse carbonate clasts occurred, cementation is by calcite precipitated from alkaline pore waters. Where local organic-rich areas of the Vanoss underwent reduction (negative Eh), siderite formed instead. Further, from the source of carbonate clasts, circulating waters had lower bicarbonate concentrations but relatively higher concentrations of aluminum and silica in solution, resulting in the precipitation of kaolinite.

The pH of the water flushing the sediments must have been in the range 4.5 to 7 (Keller, 1958, p. 240) since detrital clays were leached to kaolinite.

Where clay matrix or diagenetic clay is present, the Vanoss is invariably colored red due to the presence of hematite. The magnetic paleopole position of the study area during Pennsylvanian time (Takeuchi, Uyeda and Kanamori, 1967) suggests that the climate of the region was warm and more humid than at present. Under such climatic conditions, oxidation of iron-bearing minerals after deposition would certainly be possible. Walker (1967) provides ample evidence for post-depositional coloration by the formation on hornblende grains of delicate hematite rinds which would have been destroyed by transportation. This evidence does not preclude the oxidation of magnetite, hornblende and biotite in the source area as Krynine (1950, p. 153) proposed, or during transport. It seems likely that oxidation could have been continuing in all three stages; source, transport and depositional stages. Delicate hematite rinds are present on some iron-bearing minerals in the Vanoss thin-sections but the time of such alterations is not likely to be uniform for the entire formation.

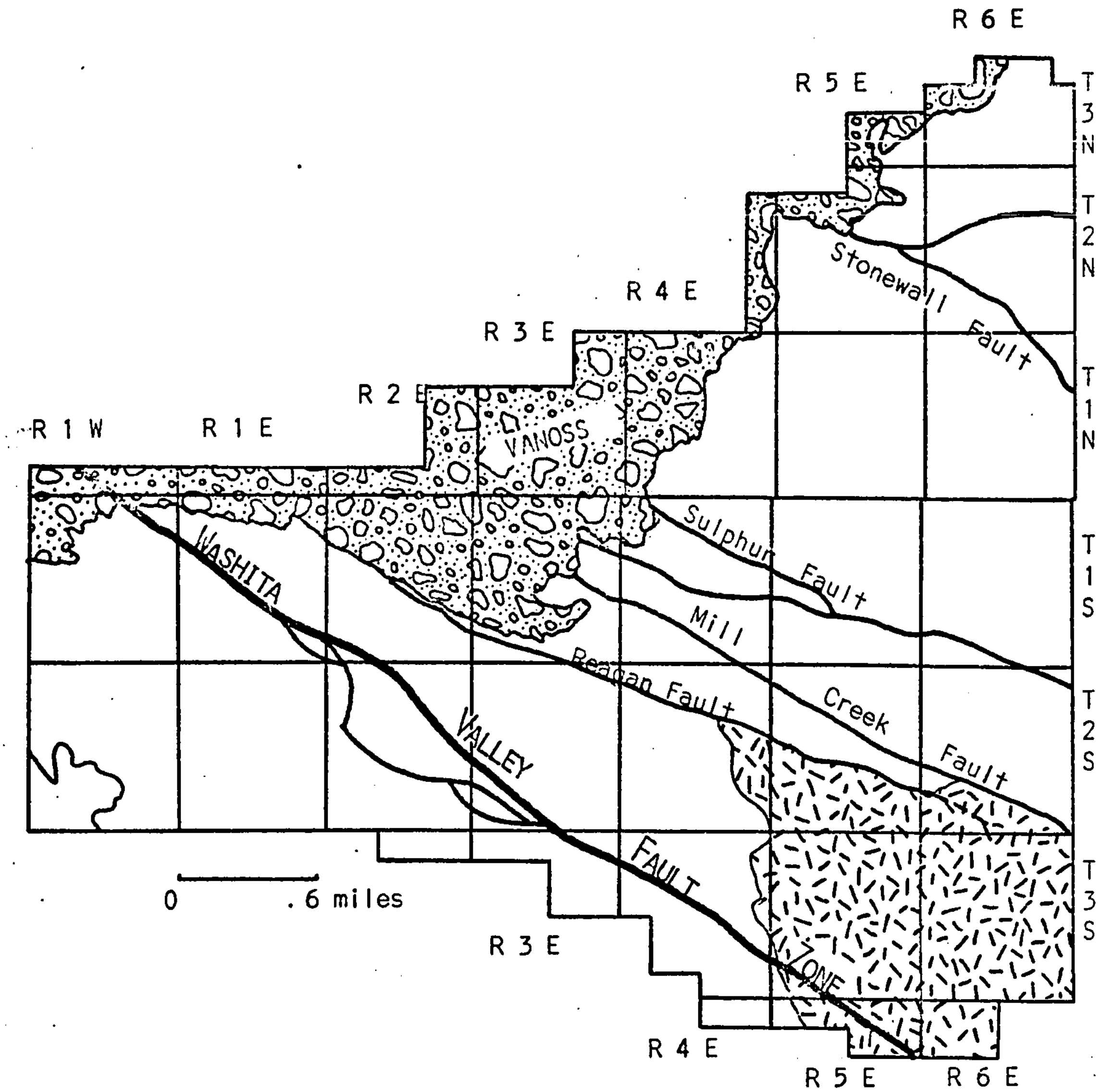
The overall depositional history based on stratigraphy and mineralogic dispersal patterns appears, therefore, to be a series of coalescing alluvial fans spreading northward from two highland areas; one trending approximately east-west through T. 2-3 S. and another smaller area situated T. 2 S. and T. 3-4 N., R. 5-6 E.

The nearest present-day exposure of the core granite to the igneous concentration in Vanoss sandstones (T. 3-4 N.) lies 28 miles south-southeast. Therefore, if the present area of exposure of the granite is taken to be the sourceland for the igneous clasts, some tectonic movement is needed to explain the present geographic separation between source and sedimentary rock. Since the northern boundary of the granitic exposure is presumably on the upthrown side of an oblique slip fault (Ham, 1969), it is assumed that vertical displacement along that plane afforded erosion of the granite along a northwestward paleoslope. Barring other evidence, it seems logical that the movement was related to movement along the major fault in the Arbuckles, the Washita Valley Fault (see fig. 39) but certainly additional work would be needed to define the structural picture.

North of T. 4 N., R. 4 E. an alluvial plain containing meandering, sluggishly-flowing streams transported finer-grained clastics northward from the source areas. The shale and interlayered lenses of sandstone, both of which are, in part, feldspar-bearing, may have merged with material derived from another source (undefined). This is inferred from the presence of unusual evaporitic chert, as defined by Folk, and, in the area of deltaic sandstones in the northern portions of T. 7 N., R. 5 E., a shift in dip direction to west rather than the north-northwest of T. 6 N., R. 5 E.

Based on analysis of thin-sections and X-ray diffractograms, the following is the most likely sequence of events during Vanoss time (see fig. 40):

1. Kaolinite forms in the granite by leaching of K-feldspar and potassium-rich phases of perthite along cleavage and/or composition planes; environmental pH was in the range 4.5 to 7 with abundant rainfall.
2. Abrasion of feldspars and carbonate rock fragments during erosion raised the groundwater pH above 7.8 and calcite spar cement formed.
3. In areas where organic activity was intense, siderite or ferroan calcite formed, partially dissolving older calcite cement. Where boggy areas occurred, siderite



Location of Principal Faults and Granite Exposures

(Patterned Area) in the Arbuckle Mountains, Oklahoma.

Figure 39

Igneous Source

Quartz and Accessories

Feldspars Kaolinite

hydrolysis

Sedimentary Source

Sandstones and

Carbonate Rocks

disintegrate to yield

Carbonate Clasts and

Overgrown Quartz Grains

TRANSPORTATION

↓

Limited Carbonate Cementation
calcite; pH 7.8, Eh is +
siderite; pH 7.0, Eh is -

↓

DETRITAL CLAY ALTERATION AND DIAGENETIC CLAYS FORMING

↓

Kaolinite
pH 4.5-7, Eh + or -

↓

Coarse Sparry Calcite
pH 7.8, Eh is +

Figure 40

PARAGENESIS

and pyrite formed (negative Eh). In more oxygenated (positive Eh) portions hematite occurs commonly with the calcite and probably is diagenetic.

4. As pH again dropped below 7.8, possibly because of increasing organic activity, kaolinite formed either by hydrolysis of detrital clays and feldspar or directly from a fluid. The extent to which kaolinization of clay occurs is largely a function of permeability variations due to grain size.

5. Recrystallization from microspar to coarse spar occurred primarily south of T. 3 N. as evidenced by pore spaces lined with fine spar grading outward into coarse spar, occasionally corroding boundaries of igneous detritus; poikiloblastic textures present.

Relative Merit of Mineral Fractions for Provenance Studies

The value of studying the Vanoss Formation for determining mineralogic dispersal patterns was that the source rock lithology was known and variations in mineralogy observed in the Vanoss could be compared to the mineralogy of the igneous source rock. A generalization based on the results is that the greatest useful provenance data were generated by studying the light mineral fraction. Diagenetic changes in the clay mineralogy and heavy mineral fraction often masked the true nature and location of the source areas.

If a geologist, in the future, were to study the Vanoss, not knowing the location of source areas, how would he be able to interpret the location and nature of the source areas and the environment of deposition of the Vanoss?

1. The predominant heavy minerals of the nonopaque fraction (72 per cent) were zircon, tourmaline and rutile. This high Z-T-R percentage is usually taken to indicate a source area containing mostly older sedimentary rocks (e.g., Hubert, 1960). Nearly one-half of the remaining 28 per cent of the nonopaques are garnet, suggesting a significant contribution to the Vanoss from metamorphic rocks. However, the composition of the light mineral fraction, stratigraphic relationships, tectonic history and present pre-Vanoss outcrop patterns leave no doubt that granitoid rocks were a most important contributor to Vanoss sediments. Also, metamorphic rocks containing garnet are present in the source area only as inclusions in the granite. No metamorphic terrain is present. There simply are no heavy minerals unique to the granite which would characterize the ultimate source as being igneous rather than metamorphic crystalline rocks.

2. Because there are no diagnostic heavy minerals in a granite, the light mineral fraction is better than heavies for source rock identification in the Vanoss. Besides microcline-perthite and granite rock fragments being diagnostic of the granitic source rock,

polycrystalline quartz consisting of two to five crystals is igneous in origin (Blatt, 1967) and is most common nearest the plutonic source area for the Vanoss. Decrease in abundance of polycrystalline quartz away from the granite is due to a combination of disintegration of those grains, dilution from sedimentary sources, and grain-size decrease with transportation.

3. According to Slemmons' work (1962) the ratio of albite-twinned plagioclase to Carlsbad-twinned plagioclase is 9:5 for igneous rocks and 31:2 for metamorphic rocks. In the Vanoss sediments the ratio was 79:8 or clearly resembling plagioclase from metamorphic rocks. The unusual ratio in the Vanoss is due to chemical and mechanical disintegration of larger polysynthetically-twinned grains which still retain several lamellae in each smaller grain owing to the fine size of twinning. Since Carlsbad twins are essentially single twins composed of 2 or 3 subindividuals, their breakdown leads to a more drastic reduction of Carlsbad-twinned plagioclase than albite-twinned feldspars.

4. The original clay mineralogy is largely obliterated by diagenetic reconstitution to kaolinite. The original content is best indicated in argillaceous sediments. The illite probably was derived from the

Paleozoic marine carbonate source rocks and the detrital kaolinite from the weathering of igneous feldspar in the source area.

Clearly certain concepts popular with sedimentary petrologists, today, need careful reevaluation based on the data derived from this study. Misinterpretation of these data would lean to an incorrect understanding of the geologic history of the Vanoss.

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APPENDICES

APPENDIX A

VANOSS MINERALOGY BY THIN-SECTION ANALYSIS

General Statement

Data in this appendix are subdivided into nine categories. An explanation for abbreviations used in each section is included below. All values are percentages to nearest 0.1 per cent.

Section	Remarks
1. Location	Location by 1/4 section, Township and Range.
2. Thin Section	Four figit randomly selected identification.
3. Quartz	$\bar{X}/\bar{\rho}$ = Mean Grain Size/Mean Roundness
	MNU = monocrystalline nonundulatory quartz
	MU = monocrystalline undulatory quartz
	Pxl = polycrystalline quartz
	Vein = percentage of quartz, this variety
	Overgrown = percentage of quartz overgrown with quartz
4. Feldspar	$\bar{X}/\bar{\rho}$ = as in section 3, above
	Pla = Plagioclase
	Mic = Microcline
	Per = Perthite
	Ort = Orthoclase

Alb = Albite twins as percentage of total Plagioclase

Fel = Feldspar

Car = Carlsbad twins as percentage of total Plagioclase

Alb-Car = Combined twins

Others = Other types of twin laws, undivided

Altered = Feldspar unidentifiable due to weathering

5. Heavy Minerals — Heavy Minerals and per cent concentration of entire rock.

Hem = Hematite

Bio = Biotite

Hor = Hornblende

Mag = Magnetite

Rut = Rutile

Epi = Epidote

Apa = Apatite

Pyr = Pyrite

Ilm = Ilmenite

Gar = Garnet

Sph = Sphene

Tou = Tourmaline

Zir = Zircon

6. Clay Minerals — Clay Minerals which are not acting as cement.

Kao = Kaolinite percentage

Mon/Chl = Montmorillonite or chlorite percentage

(c = chlorite, m = montmorillonite)

Unidentified = Ironstained, unidentifiable clays

7. Rock Fragments — GRFs = Granite rock fragment percentage

LmRFs = Limestone rock fragment percentage

MRFs = Metamorphic rock fragment percentage

Others = minor amounts of sedimentary and igneous rocks with dominant type letter above subordinate amount.

s = sandstone

sh = shale

v = volcanic or dike rock fragments

F = invertebrate fossil fragments

8. Cements — Authigenic cementing agents; clays are ironstained.

Sid/Dol = siderite or dolomite cementing agents.

s = siderite

d = dolomite

9. Rock Name — Abbreviations for McBride and Revised sandstone rock names. Limestones are named according to Folk's classification.

FLSS = Feldspathic Lithic Sandstone

LSS = Lithic Sandstone

LA = Lithic Arkose

A = Arkose

LSA = Lithic Subarkose

SA = Subarkose

SLSS = Sublithic Sandstone

QSS = Quartzose Sandstone

Con = Conglomerate

L = Limestone

Location	Thin Section	Elevation (ft.)	Quartz $\bar{X}/\bar{P}$	Quartz MNU	Quartz MU	Quartz Pxl	Quartz Vein (% Qtz)	Quartz Overgrown (% Qtz)	Feldspar $\bar{X}/\bar{P}$	Feldspar Pla	Feldspar Mic	Feldspar Per	Feldspar Ort	Feldspar Altered or Untwinned	Twin Types Alb (% Fel)	Twin Types Car	Twin Types Alb-Car	Twin Types Others	Heavy Minerals Name (%)	Clay Minerals Kao	Clay Minerals Illite	Clay Minerals Mon/Chl	Clay Minerals Undefined	Rock Fragments CRFs	Rock Fragments LmRFs	Rock Fragments MRFs	Rock Fragments Chert	Rock Fragments Others	Cements Calcite	Cements Silica	Cements Clays	Cements Sid/Dol	Rock Name (McBride/Revised)
SW/4, 7-2S-5E	7057		1.2/1.8	2.5		5.0			0.5/1.5	5.0		5.0												82.5				3.3F	57.7				FLSS/FLSS
NE/4, 3-1S-1W	3435		3.5/1.0	6.0	0.3				2.3/1.8	2.0		0.7		0.3																			A/Con
NW/4, 8-1S-1W	8614		2.0/2.6	10.3	3.4		18.8	12.5													2.6		0.9		22.4		28.4	0.9s	31.0				LSS/Con
SE/4, 2-1S-1E	8299		2.0/2.7	30.4	18.1	3.5	5.6	1.1	2.5/2.2	0.6									Hem(0.6)					0.6	9.9		2.9	4.1vFs	28.7				SLSS/QSS
NE/4, 10-1S-1E	9675		2.1/3.3	24.0																	1.3		22.7		8.0		4.0		40.0				SLSS/Con
NW/4, 3-1S-2E	1538	901	1.1/2.4	16.7	7.3	2.7	7.5	2.5	1.0/2.0	4.0	1.3	6.3	1.0	6.3	100.0					0.7				11.3	4.3		0.3	5.7v	32.0				FLSS/LA
NW/4, 3-1S-2E	8594	892	1.4/2.4	18.0	10.0	2.0	4.4	1.1	0.8/2.1	6.0	1.0	8.7			88.0		12.0		Epi(0.3) Pyr(0.3) Bio(0.4)				0.3	5.3	5.3			0.7v	33.0				LA/A
SE/4, 5-1S-2E	9861	838	1.5/2.7	20.7	8.3	1.7	6.5	2.2	0.7/1.8	4.0	1.0	5.7	0.3	6.3	67.0		16.7	16.7	Hem(4.7)		6.3		2.0	1.0	10.3		8.3	1.7vs	16.0				LA/A
SE/4, 5-1S-2E	4753	840	0.9/2.2	20.0	11.7	3.3	4.7		0.6/1.6	0.7	1.3	13.3	1.0	1.0	50.0		50.0		Hor(0.3)	6.3	0.3			5.7	7.7		2.3	1.0s	24.0				LA/A
NE, 14-1S-2E	5516	1020	1.7/2.9	28.2	7.1	2.1			0.8/1.4	0.4	0.7	2.8		1.8			100.0			0.7	0.4			3.2	19.4		1.4		31.8				LSS/
SE/4, 17-1S-2E	9688	830	2.5/2.9	1.0				100.0																	51.7		4.7	0.7F	41.9				L[a]
NE/4, 19-1S-2E	2485	810	2.0/3.0	40.0	6.3	0.7	0.7	31.2	1.8/2.2					5.0					Bio(0.3)	1.3			1.0	0.3	14.0		7.0	2.0v	22.3				SLSS/Con
NE/4, 1-1S-3E	2041	1090	1.6/2.1	21.3	10.0	1.7	5.1	9.1	1.0/1.6	1.7	0.7	4.0	1.0	3.0			1.5		Hem(5.7) Mag(0.3) Bio(0.3)	0.3	1.7		9.7	6.0	11.3		1.7	0.3v	19.3				FLSS/LSA
SW/4, 1-1S-3E	9452	1150	1.7/2.7	10.8	3.8	0.8	10.0		0.8/2.0	2.3	1.5	3.8	0.8		67.0			33.0	Hor(0.8)		1.5			2.3	14.6		0.8	0.8v	53.8				FLSS/A

Location	Thin Section	Elevation (ft.)	Quartz: $\bar{X}/\bar{\rho}$	Quartz: MNU	Quartz: MU	Quartz: Pxl	Quartz: Vein (% Qtz)	Quartz: Overgrown (% Qtz)	Feldspar: $\bar{X}/\bar{\rho}$	Feldspar: Pla	Feldspar: Mic	Feldspar: Per	Feldspar: Ort	Feldspar: Altered or Untwinned	Twin Types: Alb (% Fel)	Twin Types: Car	Twin Types: Alb-Car	Twin Types: Others	Heavy Minerals: Name (%)	Clay Minerals: Kao	Clay Minerals: Illite	Clay Minerals: Mon/Chl	Clay Minerals: Undefined	Rock Fragments: GRFs	Rock Fragments: LmRFs	Rock Fragments: MRFs	Rock Fragments: Chert	Rock Fragments: Others	Cements: Calcite	Cements: Silica	Cements: Clays	Cements: Sid/Dol	Rock Name (McBride/Revised)
NW/4, 2-1S-3E	6808	1005	1.8/2.5	24.8	10.3	1.5			0.9/1.7		2.3	2.3						1.1	Hem(0.8) Hor(0.4) Epi(0.4) Bio(0.4)				0.4	0.4	21.8		1.9	0.4s	29.0				LSS/SA
SW/4, 10-1S-3E	5821	1030	1.9/2.8	24.2	5.5	2.2	10.3		1.0/1.7	1.1	1.1	3.3	1.1	2.2			100.0		Hor(1.1)	1.1	1.1		1.1	3.3	23.1		5.5		20.9		1.1		FLSS/SA
SE/4, 11-1S-3E	8100	1080	1.8/2.8	23.6	5.8	0.9			1.3/2.0	0.9	0.4	1.8		2.2	100.0				Hem(1.3)	2.2	4.0		1.3	0.9	21.3		3.6	0.9vs	28.4				LSS/SA
SE/4, 15-1S-3E	7588	1058	2.2/2.5	33.7	9.7				2.2/2.1	0.3	0.3			1.3	100.0				Hem(0.7)				1.3	0.3	26.7		2.7		23.0				LSS/QSS
SE/4, 16-1S-3E	9576	1035	1.9/2.1	53.7	25.3	1.0	6.7	10.0	1.1/1.9	0.7		1.3	0.7	2.0	100.0					0.3			7.3	1.7							6.0		SA/SA
NW/4, 28-1S-3E	4623	895	1.8/2.9	21.0	4.4	1.1	6.3		0.7/1.6	0.6	0.6	6.1	0.6	2.2	100.0						0.6			0.6	18.3		5.6	1.1F	37.2				FLSS/Con
SE/4, 30-1S-3E	9080	959	2.1/3.5	23.2	7.0				1.0/2.5	0.7					100.0										31.0		7.0	7.0Fs	23.9				LSS/Con
NE/4, 25-1N-3E	5949	1120	1.2/2.5	20.7	6.3	0.3	1.2	7.3	0.7/1.7	0.7	0.7	4.7		3.3	100.0				Hem(0.3)	2.0	1.0		1.3	4.3	30.0		4.0	2.3vs	18.0				FLSS/LSA
SW/4, 25-1N-3E	0824	1125	1.3/2.7	11.5	6.5	0.5	5.0		0.8/2.1	0.5	0.9	3.7	0.5	4.6	100.0						0.5			4.1	23.0		3.2	3.2Fv	37.3				FLSS/LA
SE/4, 26-1N-3E	7915	1067	2.0/2.6	21.7	9.7	1.0	22.7	31.9	1.6/1.7		0.7	7.0	1.3	2.0					Hem(1.7) Mag(1.0) Bio(0.7)	0.3	0.7		2.7	2.7	17.7		3.0	0.7v	25.7				FLSS/A
SE/4, 26-1N-3E	1677	1067	1.6/2.1	30.7	10.0	1.3	7.1	13.5	1.6/1.2	0.7	1.3	2.7	1.0	2.7	100.0				Ilm(0.3) Mag(0.3) Bio(0.3)	2.7			0.3	2.7	19.3		2.7	0.7v	20.3				FLSS/SA
SE/4, 26-1N-3E	4290	1050	2.2/2.4	17.0	3.4	2.0			1.2/2.1	1.4		2.7						1.4						2.0	24.5		2.7	2.0sF	41.5				LSS/SA
NW/4, 30-1N-3E	9715	1130	1.6/2.6	22.0	6.0	2.0			0.9/1.9			4.0							Hem(2.0) Hor(2.0)	2.0	6.0		4.0	4.0	28.0		2.0	2.0v	12.0				(CP#1) LSS/LSA

			Quartz						Feldspar						Twin Types				Heavy Minerals	Clay Minerals				Rock Fragments					Cements				Rock Name
Location	Thin Section	Elevation (ft.)	$\bar{X}/\bar{\rho}$	MNU	MU	Pxl	Vein (% Qtz)	Overgrown (% Qtz)	$\bar{X}/\bar{\rho}$	Pla	Mic	Per	Ort	Altered or Untwinned	Alb (% Fel)	Car	Alb-Car	Others	Name (%)	Kao	Illite	Mon/Chl	Undefined	GRFs	LmRFs	MRFs	Chert	Others	Calcite	Silica	Clays	Sid/Dol	(McBride/Revised)
NW/4, 30-1N-3E	9840	1133	$\frac{3.3}{2.4}$	25.0	9.7	1.0		0.9	$\frac{3.0}{1.9}$	1.0	0.7	1.7			100.0			3.0	Mag(0.3) Hor(0.3) Bio(0.3)	2.3	0.7				4.3		0.7		48.7		0.3		(GP#2) SA/SA
NW/4, 30-1N-3E	8930	1152	$\frac{2.2}{2.6}$	26.3	12.1			5.5	$\frac{1.1}{1.8}$		1.1	1.1	1.1					3.7		1.1	0.5		0.5	1.6	20.5		1.6	2.1s^{F}	30.5				(GP#4) LSS/SA
NW/4, 30-1N-3E	5005	1146	$\frac{1.7}{2.6}$	22.7	2.3	0.3		1.3	$\frac{0.8}{1.5}$	0.7	1.7	4.0	0.7		50.0	50.0		1.0	Hem(0.7) Hor(0.3) Epi(0.3) Gar(0.3)		1.3	0.7c	0.7	3.3	20.0		5.0	1.0s	33.0				(GP#5) FLSS/SA
NW/4, 30-1N-3E	3175	1160	$\frac{3.4}{1.8}$	6.3	1.7				$\frac{3.0}{1.2}$	0.7	0.3			3.7	100.0									0.3	2.7		0.3		84.0				(GP#6) LA/A
SE/4, 36-1N-3E	4262	1090	$\frac{0.8}{2.0}$	22.0	6.3	1.0	5.7	8.0	$\frac{1.0}{1.8}$	0.3	1.7		1.0	8.0						1.3	0.3		3.0	3.0	21.3		2.0	1.3v	27.0				FLSS/Con
SE/4, 36-1N-3E	1605	1092	$\frac{1.0}{2.5}$	12.6	7.4	0.6			$\frac{0.2}{1.6}$			2.9	0.6	1.1					Hem(0.6)					3.4	30.9		3.4	0.6s	36.6				LSS/Con
NW/4, 6-2N-5E	6616	1180	$\frac{1.5}{2.6}$	16.0	6.7	1.3	9.7	5.6	$\frac{1.6}{1.8}$	2.0	0.3	6.3	0.7	4.7	50.0		50.0		Mag(0.3) Gar(0.3) Bio(0.7)	0.7			0.7	15.7	14.0		0.3	0.3v	28.3			0.3s	FLSS/FLSS
SW/4, 3-2N-4E	0752	1145	$\frac{0.6}{2.0}$	18.7	11.3	3.5	9.5		$\frac{0.7}{2.0}$	8.8	8.8	2.8	1.1		29.5	3.3		8.2		0.4				20.1	0.7				23.7				LA/LA
NE/4, 3-2N-4E	6832	1191	$\frac{0.8}{1.8}$	11.7	5.7	2.0			$\frac{0.6}{2.2}$	1.7	1.7	11.3		3.7	100.0				Bio(0.7) Mag(0.3) Hor(0.3)	1.7	1.3			22.0	1.3			2.7s^{v}	31.7		0.3		FLSS/FLSS
NE/4, 6-2N-4E	2266	1120	$\frac{3.6}{1.2}$	7.0	2.0	0.7	6.9	10.3	$\frac{2.8}{1.2}$	1.3	0.7	1.0	0.7	1.7	100.0				Bio(2.0) Mag(0.3) Hem(0.7) Hor(0.3)				1.3	1.7				1.0v^{F}	58.0				LA/LA
NE/4, 10-2N-4E	8515	1160	$\frac{3.2}{2.2}$	15.3	10.3	3.0	4.7	7.0	$\frac{2.2}{1.6}$	6.0	1.0	7.0	0.7	4.3	83.3	5.6		11.1	Bio(0.7) Mag(0.3) Hor(0.3) Epi(0.3)	3.3	1.0		4.3	6.0	1.3		0.3	0.3v	29.3		4.7		LA/LA

			Quartz						Feldspar						Twin Types				Heavy Minerals	Clay Minerals				Rock Fragments					Cements				Rock Name
Location	Thin Section	Elevation (ft.)	$\bar{X}/\bar{\rho}$	MNU	MU	Pxl	Vein (% Qtz)	Overgrown (% Qtz)	$\bar{X}/\bar{\rho}$	Pls	Mic	Per	Ort	Altered or Untwinned	Alb (% Fel)	Car	Alb-Car	Others	Name (%)	Kao	Illite	Mon/Chl	Undefined	GRFs	LmRFs	MRFs	Chert	Others	Calcite	Silica	Clays	Sid/Dol	(McBride/Revised)
SE/4, 10-2N-4E	5575	1239	$\frac{1.3}{1.9}$	20.7	6.7	4.7			$\frac{1.0}{1.7}$	2.3	1.7	11.0	1.0	5.3	71.4			28.6	Hem(2.7) Bio(0.3) Hor(0.3) Mag(0.3)				4.0	7.3	3.0				18.0			10.7?n	LA/LA
NE/4, 14-2N-4E	4456	1248	$\frac{2.3}{3.1}$	31.4	5.0																				13.6		2.9	1.4s	45.7				LSS/QSS
SW/4, 20-2N-4E	9162	1212	$\frac{1.8}{2.8}$	15.8	4.9	4.4	10.9		$\frac{0.8}{1.8}$	0.5		3.3	0.5	2.2	100.0				Hem(1.6) Hor(0.5)	1.6	1.1		0.5	3.8	31.1		2.7	1.1s	24.0				LSS/LSA
SE/4, 21-2N-4E	4693	1278	$\frac{1.9}{2.0}$	24.7	5.0	3.0	1.0	4.1	$\frac{1.6}{1.7}$	2.7	1.3	9.7	0.7	6.3	62.5			37.5	Bio(3.3) Hem(0.3)	4.7	2.0		2.3	1.3	1.7		2.7	1.3v	27.0				A/A
NE/4, 30-2N-4E	8488	1140	$\frac{2.2}{2.1}$	26.0	7.0	1.0	4.9	6.9	$\frac{1.4}{1.9}$	1.7	1.0	5.3		3.3	40.0		40.0	20.0	Hem(2.7) Hor(0.3)			0.3	0.3	3.7	9.3		3.0		35.0				LSA/SA
SW/4, 32-2N-4E	6980	1250	$\frac{2.2}{2.2}$	33.0	13.3	0.3	5.7	39.0	$\frac{2.2}{1.6}$	1.3	0.3	2.0	0.7		100.0				Bio(1.0) Hem(0.7) Hor(0.7) Mag(0.3)	0.7			2.7	1.7	2.0		0.7		31.0			5.0s	SA/SA
SE/4, 2-3N-4E	1316	1040	$\frac{0.9}{2.1}$	18.7	10.0	2.7	16.0	7.4	$\frac{1.2}{1.9}$	7.3	3.0	3.0	0.3	4.0	59.1		13.6	27.3	Bio(1.0) Mag(0.3) Epi(0.3)	0.3			1.3	23.7	0.3	0.3			23.3				FLSS/FLSS
NW/4, 33-3N-4E	8354	1065	$\frac{0.3}{2.2}$	8.3	5.3	5.0	14.3		$\frac{0.0}{2.2}$	4.3	1.3	7.7	0.7	5.0	61.5		23.0	15.4	Hor(0.7) Rut(0.3) Hem(0.3) Apa(0.3)				3.3	21.0	1.7			0.3v	34.3				FLSS/FLSS
SW/4, 2-3N-4E	5336	1010	$\frac{1.1}{2.1}$	20.7	8.0	1.7	5.5		$\frac{1.0}{2.0}$	5.7		10.3	0.3	6.3	82.3	5.9		11.8	Bio(0.3) Mag(0.3) Hem(0.3) Epi(0.3)				0.3	10.0	2.3			1.0v	32.0				LA/LA
NE/4, 3-3N-4E	4095	1010	$\frac{1.1}{2.0}$	18.0	7.3	3.7	9.2	5.7	$\frac{1.0}{1.9}$	8.0	3.0	5.0	1.0	5.7	75.0	16.7	8.3		Bio(2.0) Epi(0.7) Hor(0.3)	0.3			1.0	11.7	1.7		0.3	1.0$\overset{v}{s}$	28.7			0.7d	LA/LA
NW/4, 4-3N-4E	4286	1030	$\frac{0.5}{1.8}$	18.7	7.7	4.0	2.2	1.1	$\frac{0.5}{2.2}$	6.7	2.0	10.7	2.0	6.0	75.0	10.0	10.0	5.0	Rut(0.7) Hor(0.3) Bio(0.3) Mag(0.3)	0.3			4.7	15.3	1.0		0.3	1.0v	18.0				LA/LA

Location	Thin Section	Elevation (ft.)	Quartz						Feldspar						Twin Types				Heavy Minerals	Clay Minerals				Rock Fragments					Cements				Rock Name
			$\bar{X}/\bar{\rho}$	MNU	MU	Pxl	Vein (% Qtz)	Overgrown (% Qtz)	$\bar{X}/\bar{\rho}$	Pla	Mic	Per	Ort	Altered or Untwinned	Alb (% Fel)	Car	Alb-Car	Others	Name (%)	Kao	Illite	Mon/Chl	Undefined	GRFs	LmRFs	MRFs	Chert	Others	Calcite	Silicas	Clays	Sid/Dol	(McBride/ Revised)
NE/4, 5-3N-4E	7435	1092	$\frac{1.3}{1.9}$	13.7	3.7	2.0	10.3		$\frac{1.1}{1.8}$	6.3	2.3	6.7	2.3	2.7	63.2		21.1	14.3	Bio(1.3) Hor(0.7)				1.0	13.7	1.0		0.3	0.3sh	42.0				LA/LA
NE/4, 5-3N-4E	7434	1092	$\frac{3.7}{2.7}$	38.0	7.3	1.0	2.9	5.0	$\frac{3.7}{1.4}$	2.3	0.7	1.0	1.3	1.7	85.7			14.3	Mag(0.3) Apa(0.3)		0.7	0.7c	5.3	0.3			1.0	2.6sh	35.0				SA/SA
SW/4, 12-3N-4E	8517	1070	$\frac{0.7}{2.3}$	8.3	6.3	4.3	10.5		$\frac{0.3}{2.1}$	3.0	1.3	10.3	0.7	6.3	77.8	11.1	11.1		Bio(0.7) Hem(0.3) Hor(0.3) Sph(0.3)					17.6	4.0		0.3		34.3			0.7s	LA/LA
NW/4, 9-3N-4E	8681	1035	$\frac{3.1}{2.1}$	19.0	11.3	3.7	4.9	2.9	$\frac{3.5}{1.8}$	2.7	0.3			5.0	100.0				Bio(0.7) Hem(1.0)		4.0		3.3	1.3	0.7		0.7	0.3sh	46.0				SA/SA
NW/4, 17-3N-4E	3376	1095																							46.0			31.0F	23.0				L[b]
ECL, 18-3N-4E	8161	1240	$\frac{1.4}{2.5}$	17.3	7.7	1.0	11.5		$\frac{1.2}{1.8}$	7.0	2.7	4.3	2.7	3.7	76.2		9.5	14.3	Bio(1.7) Mag(0.7) Epi(0.3)		1.7		2.0	19.3			0.3	1.0v	26.7				LA/LA
SE/4, 31-3N-4E	9513	1105	$\frac{2.1}{2.3}$	22.0	8.7	1.3	6.3	3.1	$\frac{2.3}{1.6}$	4.7	0.7	5.7	1.7	7.3	92.9	7.2			Bio(3.0) Epi(0.3) Ilm(0.3)	1.7	1.0		1.3	4.7	3.0		2.0		28.3		1.3		LA/LA
SE/4, 31-3N-4E	5111	1105	$\frac{0.2}{2.4}$	19.0	8.5	2.4	5.4		$\frac{0.4}{2.2}$	4.9	1.6	2.8	0.8	1.2	75.0		16.7	8.3	Bio(0.3) Hor(0.3)	0.4	0.8			11.7	6.1		0.4	0.8v	37.7				FLSS/LSA
NW/4, 33-3N-4E	2764	1065	$\frac{0.8}{2.0}$	7.3	4.7	4.7	2.0		$\frac{0.7}{2.0}$	5.3	4.7	8.0	0.7	4.3	74.1	7.1		18.8	Bio(0.7)				1.0	12.0	1.7			2.3$\overset{v}{s}$	42.7				LA/LA
NW/4, 33-3N-4E	9189	1080	$\frac{0.8}{2.3}$	15.7	9.0	4.3	9.2		$\frac{0.7}{1.9}$	6.0	2.0	6.3	1.7	6.3	50.0	11.1	11.1	27.8	Hem(0.7) Bio(0.3) Epi(0.3)				4.3	11.3	1.3			0.7v	29.7				LA/LA
NW/4, 33-3N-4E	0439	1082	$\frac{2.7}{2.2}$	21.0	7.0	1.7	10.1	2.2	$\frac{2.6}{1.6}$	9.3	3.7	1.3	2.7		71.4		7.1	21.4	Bio(4.7) Hem(1.7) Mag(0.3)	3.0	0.3			3.7	6.0		1.7	0.7$\overset{s}{sh}$	25.7		7.0		LA/A
SE/4, 34-3N-4E	1342	1150	$\frac{1.6}{3.1}$	22.0	10.7	4.0	7.3	11.8	$\frac{1.9}{1.6}$	7.0	1.0	4.0	1.0	5.3	81.0	4.8	9.4	4.8	Bio(2.3) Hor(0.7)		0.7	0.3c	2.0	18.3	0.7			0.7v	18.7		0.7		FLSS/LA
NE/4, 6-3N-5E	0033	982	$\frac{0.9}{2.3}$	13.3	11.7	2.0			$\frac{0.7}{2.3}$	14.0	4.7	6.0	4.0	0.3	75.0		25.0		Bio(2.0) Hem(1.0)	1.3	1.6		1.3	10.3	3.7				17.3				LA/LA

Location	Thin Section	Elevation (ft.)	Quartz $\tilde{X}/\tilde{\rho}$	Quartz HNU	Quartz HU	Quartz Pxl	Quartz Vein (% Qtz)	Quartz Overgrown (% Qtz)	Feldspar $\tilde{X}/\tilde{\rho}$	Feldspar Pla	Feldspar Mic	Feldspar Per	Feldspar Ort	Feldspar Altered or Untwinned	Twin Types Alb (% Fel)	Twin Types Car	Twin Types Alb-Car	Twin Types Others	Heavy Minerals Name (%)	Clay Minerals Kno	Clay Minerals Illite	Clay Minerals Mon/Chl	Clay Minerals Undefined	Rock Fragments CRFs	Rock Fragments LmRFs	Rock Fragments MRFs	Rock Fragments Chert	Rock Fragments Others	Cements Calcite	Cements Silica	Cements Clays	Cements Sid/Dol	Rock Name (McBride/Revised)
NE/4, 6-3n-5E	5855	981	$\frac{0.4}{1.8}$	19.3	8.3	2.3	3.3	2.2	$\frac{0.4}{2.0}$	5.3	1.3	12.3	0.3	7.3	68.8	12.5		18.8	Bio(1.3) Hem(0.3)	2.3	0.3		0.3	17.0			0.3	1.0v^{s}	20.3				LA/LA
NE/4, 6-3N-5E	0112	980	$\frac{0.8}{2.2}$	25.3	12.3	1.7	30.5	10.2	$\frac{1.2}{1.8}$	14.3	6.7	7.7	2.0	0.7	81.4	2.4	11.6	4.7	Bio(2.3) Hem(0.3)	1.3			3.7	3.3				0.3s	19.0				A/A
NE/4, 6-3N-5E	0521	987	$\frac{1.6}{1.9}$	17.7	9.3	2.7	13.5	6.7	$\frac{1.4}{1.9}$	9.0	5.4	7.3	6.0		74.1	3.7	7.4	14.8	Bio(6.0) Rut(0.3)	1.7	0.7		4.3	16.3	1.0		0.7	0.7s	16.7		1.3		LA/LA
NW/4, 7-3N-5E	6708	1030	$\frac{1.1}{1.7}$	20.7	4.3	0.7		2.6	$\frac{1.0}{1.8}$	5.3	2.0	11.3	1.0	8.0	56.3		18.8	25.0	Bio(1.0) Hem(0.7)		0.3			7.7	4.3		0.7	0.3v	31.3			0.3s	LA/LA
NW/4, 1-4N-4E	8482	982	$\frac{2.0}{2.1}$	28.0	19.0	2.3	12.2	17.6	$\frac{1.8}{1.7}$	3.7	0.3	0.3	0.3	4.7	91.0			9.0	Mag(0.3)	0.3	0.7	0.3c	1.3	1.3	3.0		2.7	0.7v	28.3		2.3		SA/SA
CS/2, 1-4N-4E	0001	1020	$\frac{1.7}{2.7}$	22.3	24.3	5.7	19.7	11.5	$\frac{1.9}{2.1}$	12.3	4.0	0.7	5.7		86.5		13.5		Bio(1.7) Epi(0.7)	1.0	2.3			7.3		0.7	1.3	0.3s			10.0		LA/A
NW/4, 11-4N-4E	6415	1050	$\frac{3.6}{1.6}$	35.7	10.3		2.9	2.2	$\frac{3.7}{1.3}$	0.7	0.3		0.3	2.3	100.0				Mag(1.0) Hor(0.7) Apa(0.3) Bio(0.3)	1.3	3.7			[illegible].3	0.7		0.3		40.7				SA/SA
SW/4, 11-4N-4E	1767	1049	$\frac{2.8}{1.9}$	31.7	13.0	3.7	5.5	5.5	$\frac{2.6}{1.5}$	2.0	1.0	0.3	2.0	5.3	83.3			16.7	Bio(0.3)	0.3	0.7		3.0	[illegible].3			0.7	0.7s^{v}	28.0			2.0d	SA/SA
SE/4, 13-4N-4E	7731	1060	$\frac{0.7}{2.0}$	18.3	9.3	4.3	14.6	41.7	$\frac{0.6}{1.8}$	6.3	0.7	7.3	1.3	9.3	57.9	5.3	10.5	26.3	Hor(0.3) Bio(0.3) Epi(0.3) Sph(0.3)	1.0				13.0	0.7		0.3	1.0s^{v}	25.7				LA/LA
NE/4, 13-4N-4E	2147	1052	$\frac{1.4}{2.3}$	27.3	14.7	2.3	6.8	12.0	$\frac{1.6}{1.5}$	6.3	2.0	3.0	1.0	6.3	47.4	10.5	15.8	26.3	Mag(0.3) Epi(0.3) Gar(0.3)	0.7			1.0	10.7	1.0	0.3	1.7	1.3v	15.7		1.0		LA/LA
SE/4, 19-4N-4E	1295	1122	$\frac{1.3}{2.8}$	6.0	0.7	0.3			$\frac{2.6}{1.4}$	1.3	2.3			1.0	100.0				Epi(0.3)					3.0	61.7		1.0		22.3				L^{c}
SW/4, 23-4N-4E	5282	1050	$\frac{1.4}{1.9}$	17.7	7.7	2.3	10.8	16.9	$\frac{1.2}{1.8}$	6.3	1.0	11.0	2.0	9.0	57.9	15.8	10.5	15.8	Bio(3.3) Hor(0.3)		0.3			10.7	0.3		0.7		27.3				LA/LA
W/2, 27-4N-4E	8804	1050	$\frac{0.5}{2.3}$	10.3	6.3	4.0	11.3	7.7	$\frac{0.5}{2.0}$	6.7	3.0	8.0	1.7	4.3	75.0	10.0		15.0	Mag(2.7) Hem(1.0) Bio(0.3)		1.3		4.3	12.7				3.0v	29.7				LA/LA

Location	Thin Section	Elevation (ft.)	Quartz $\bar{X}/\bar{\rho}$	Quartz MNU	Quartz MU	Quartz Pxl	Quartz Vein (% Qtz)	Quartz Overgrown (% Qtz)	Feldspar $\bar{X}/\bar{\rho}$	Feldspar Pla	Feldspar Mic	Feldspar Per	Feldspar Ort	Feldspar Altered or Untwinned	Twin Types Alb (% Fel)	Twin Types Car	Twin Types Alb-Car	Twin Types Others	Heavy Minerals Name (%)	Clay Minerals Kao	Clay Minerals Illite	Clay Minerals Mon/Chl	Clay Minerals Undefined	Rock Fragments GRF's	Rock Fragments LmRFs	Rock Fragments MRFs	Rock Fragments Chert	Rock Fragments Others	Cements Calcite	Cements Silica	Cements Clays	Cements Sid/Dol	Rock Name (McBride/Revised)
W/2, 27-4N-4E	3740	1042	$\frac{2.9}{2.1}$	38.3	12.7	4.0	5.5	14.5	$\frac{2.8}{1.6}$	3.0	1.3		0.7	5.7	55.6	11.1		22.2	Bio(0.3) Hor(0.3)	0.3	1.3		1.3	2.0		0.3	1.3		26.7				SA/SA
SE/4, 29-4N-4E	3711	1120	$\frac{1.1}{1.8}$	16.0	4.7	3.0	2.8	1.4	$\frac{0.4}{2.1}$	6.7	3.3	7.0	2.0	4.7	55.0	10.0	10.0	25.0	Bio(1.7) Hor(0.3)	0.3			6.0	11.0	3.0		0.3	0.7s v	29.3				LA/LA
SE/4, 34-4N-4E	7599	1008	$\frac{2.5}{1.9}$	16.3	8.7	2.0		2.5	$\frac{1.4}{1.6}$	5.7	2.0	7.7	1.3	7.7	76.4		17.7	5.9	Bio(1.3) Mag(0.7) Hor(0.7) Epi(0.3)	1.0			2.7	13.7			0.7	0.3v			27.3		LA/LA
SE/4, 35-4N-4E	4387	980	$\frac{1.9}{1.7}$	30.3	11.7	5.0	2.1	1.4	$\frac{1.1}{2.2}$	4.0	4.0	12.3	1.0	2.3	75.0	8.3		16.7	Mag(0.3) Hor(0.3)				1.3	6.7	1.7		0.7	1.0s	0.7		16.7		LA/A
SE/4, 31-4N-5E	6689	950	$\frac{5.0}{1.9}$	23.3	6.7	5.0		1.9	$\frac{0.8}{1.9}$	4.3	3.0	8.7	1.0	8.0	69.2		7.7	23.1					1.0	11.0			0.3	0.7s			27.0		LA/LA
SW/4, 7-5N-4E	0364		$\frac{1.9}{2.2}$	30.3	20.7	6.0	19.9	4.7	$\frac{2.2}{2.2}$	6.0	2.7		1.0	0.3					Tou(0.3)	11.0	0.3			3.0		0.7	2.0				16.0		SA/SA
N/2, 16-5N-4E	8520		$\frac{3.1}{2.0}$	46.7	22.7	2.7	6.9	9.7	$\frac{2.7}{1.8}$	1.7			1.3	4.7	80.0			20.0	Hem(1.0) Mag(0.7) Hor(0.7) Bio(0.7) Epi(0.3)	1.0	0.7		2.3	1.3			0.7	1.3sh			9.7		SA/SA
N/2, 16-5N-4E	4075		$\frac{1.6}{1.9}$	31.7	14.7	1.3	4.2	4.2	$\frac{1.8}{1.5}$	6.6	0.7	1.0	2.0	7.3	80.0	10.0		10.0	Bio(1.0) Hem(0.7) Gar(0.3)	1.7			4.0	7.7			2.0				17.3		LSA/LSA
N/2, 16-5N-4E	6944		$\frac{3.0}{0.8}$	19.3	24.3	3.0	7.9	4.3	$\frac{1.9}{0.9}$	8.0	0.3	1.3	2.0	4.3	83.3		12.5	4.2	Bio(0.3) Mag(0.3) Epi(0.3)	0.3				3.0		0.7	5.0	0.7v			26.7		SA/A
SE/4, 10-5N-4E	9832	1000	$\frac{2.4}{2.2}$	52.3	30.0	3.0	4.7	3.5	$\frac{2.4}{2.0}$	1.3			0.7	4.3	100.0				Bio(0.3) Mag(0.3) Epi(0.3)			0.3c		0.7			0.3				6.0		SA/SA
NW/4, 13-5N-4E	9407	980	$\frac{2.6}{2.1}$	27.4	24.5	2.9	4.7	11.8	$\frac{2.4}{1.8}$	1.6				2.6	80.0			20.0	Bio(0.3)	1.0	1.3		1.9	1.0	1.0		2.3	0.3	22.9		3.9	1.9	SA/SA
SW/4, 34-5N-4E	1247	1040	$\frac{1.4}{2.5}$	13.7	6.3	3.3	10.0	17.1	$\frac{1.5}{1.9}$	10.3	4.7	1.7	0.3	2.7	77.4		6.5	16.1	Hor(0.3)					9.3	11.0	0.3	1.7	2.0F	32.3				FLSS/LA

Location	Thin Section	Elevation (ft.)	Quartz $\bar{X}/\bar{\rho}$	Quartz MNU	Quartz MU	Quartz Pxl	Quartz Vein (% Qtz)	Quartz Overgrown (% Qtz)	Feldspar $\bar{X}/\bar{\rho}$	Feldspar Pla	Feldspar Mic	Feldspar Per	Feldspar Ort	Feldspar Altered or Untwinned	Twin Types Alb (% Fel)	Twin Types Car	Twin Types Alb-Car	Twin Types Others	Heavy Minerals Name (%)	Clay Minerals Kao	Clay Minerals Illite	Clay Minerals Mon/Chl	Clay Minerals Undefined	Rock Fragments GRFs	Rock Fragments LmRFs	Rock Fragments MRFs	Rock Fragments Chert	Rock Fragments Others	Cements Calcite	Cements Silica	Cements Clays	Cements Sid/Dol	Rock Name (McBride/Revised)
SE/4, 2-5N-5E	5382	950	2.8/1.9	54.0	24.7	2.0	8.7	13.2	2.9/1.6	2.3	0.3	0.7	1.0	2.3	100.0				Epi(0.7) Mag(0.3) Bio(0.3) Tou(0.3)					2.3	1.0	0.3	1.7				5.7		SA/SA
SW/4, 9-5N-5E	0088	950	2.2/2.5	37.3	23.3	5.3	22.2	24.2	2.6/2.4	2.7	0.7	0.3	4.3		50.0	12.5	12.5	25.0	Hem(1.3) Bio(0.3) Tou(0.3) Epi(0.3)	1.7				0.3		0.3	0.7	2.0s			18.7		SA/SA
NE/4, 10-5N-5E	3868	950	2.9/1.9	57.0	16.7	3.3	3.9	4.8	3.9/1.6	1.7			1.3	4.0	100.0				Mag(0.7) Epi(0.7) Hem(0.3)	1.0				1.6			2.3	1.7v sh			7.7		SA/SA
SW/4, 12-5N-5E	3875	910	2.7/3.0	44.0	16.7	3.0	4.2	8.9	2.6/3.0	3.3	1.3	1.0	0.3	4.0	70.0		10.0	20.0	Bio(1.3) Mag(0.7) Hor(0.3) Epi(0.3)	1.7				3.7		0.3	5.3	0.3v			12.3		SA/SA
NE/4, 21-5N-5E	6114	964	1.6/3.7	35.0	12.0	0.7	6.3	4.9	2.5/1.8		0.3			0.7											18.3		6.7		26.3				SLSS/QSS
NW/4, 5-5N-6E	8768	950	3.0/2.4	25.0	10.0	0.3	6.6	1.9	1.3/1.9	2.7	2.3	6.3	1.0	2.7	87.5		12.5		Hor(1.0) Rut(0.3) Gar(0.3) Bio(0.3)	2.3				3.7	9.0		0.7		27.0		3.7	1.0d	LSA/A
NW/4, 5-5N-6E	5689	930	2.2/2.4	55.0	7.7	1.0	2.1	30.4											Hem(1.0) Epi(0.3)				0.3		0.3		0.3		25.3			8.7s	QSS/QSS
N/2, 5-5N-6E	6590	930	2.1/2.4	42.7	11.3	1.0	6.1	25.5												3.3	0.3		0.3		0.3		6.0		30.7			4.0s	QSS/QSS
N/2, 5-5N-6E	1885	900	1.1/2.2	10.3	7.0	2.0	8.6		0.6/1.5	1.3		4.0		6.7	75.0		25.0		Bio(1.0) Mag(0.3) Hor(0.3) Zir(0.3)	3.7	2.3			7.0	4.3		1.0	0.3v	44.3				LA/LA
NW/4, 1-6N-5E	8995		2.0/2.2	32.7	13.0	4.3	5.3	6.0	1.8/1.9	3.0		1.3	0.7	3.0	77.8			22.2	Mag(0.3)		1.0		0.3	0.7	1.0		3.7	0.3v	20.3		4.3		SA/SA
SW/4, 3-6N-5E	6617		2.6/1.9	51.0	15.7	1.0	7.9	9.4	2.3/1.5	2.0	1.3	0.7	0.7	4.3	100.0				Hor(0.7) Bio(0.3) Epi(0.3)	1.3	0.3			1.7	0.3		1.3		11.3		5.7		SA/SA

			Quartz						Feldspar							Twin Types			Heavy Minerals	Clay Minerals				Rock Fragments					Cements				Rock Name
Location	Thin Section	Elevation (ft.)	$\bar{X}/\bar{\rho}$	MNU	MU	Pxl	Vein (% Qtz)	Overgrown (% Qtz)	$\bar{X}/\bar{\rho}$	Pla	Mic	Per	Ort	Altered or Untwinned	Alb (% Fel)	Car	Alb-Car	Others	Name (%)	Kao	Illite	Mon/Chl	Undefined	GRFs	LmRFs	MRFs	Chert	Others	Calcite	Silica	Clays	Sid/Dol	(McBride/ Revised)
SE/4, 10-6N-5E	2988		2.8/1.8	52.3	16.0	3.3	4.2	1.4	2.8/1.3	1.7	0.7	0.3	0.3	3.0	100.0				Hor(0.3) Epi(0.3)				0.7	1.3		0.7	0.7		13.3		4.3	0.7d	SA/SA
SE/4, 10-6N-5E	1080		2.5/2.7	36.3	24.0	3.0	7.9	1.6	2.7/1.9	4.3	1.7	1.0		5.0	76.9			23.1	Bio(1.0) Mag(1.0) Hem(0.3)					8.7		1.0	4.0				8.7		LSA/LSA
SE/4, 12-6N-5E	2065		3.0/1.8	53.4	14.1	3.4	5.3	8.7	2.9/1.6	2.8	0.7			5.2	87.5			12.5	Epi(1.4) Tou(0.7) Hor(0.7) Hem(0.3)			1.0c		5.9		0.7	3.4				6.2		SA/SA
NE/4, 13-6N-5E	8771	961	2.2/2.1	45.0	28.3	3.0	3.9	7.4	2.9/1.8	4.0	0.3	2.0	1.3	5.0	100.0				Bio(0.3) Hor(0.3) Hem(0.3)					0.7			4.0	1.0sh			4.3		SA/SA
SW/4, 36-6N-5E	6712	970	2.7/2.1	55.3	24.0	2.0	7.0	13.5	2.9/1.2	2.3	0.7	0.3	0.7	2.7	100.0				Mag(0.3)					1.7			1.3	0.3v			8.3		SA/SA
NW/4, 5-6N-6E	4992		3.1/2.2	54.0	19.7	1.7	3.1	2.7	3.0/1.8	1.3		0.7	0.3	6.0	100.0				Gar(0.7) Mag(0.3) Hem(0.3)			0.3c		1.0		0.3	2.3				11.0		SA/SA
NE/4, 6-6N-6E	5565		2.4/1.9	54.0	20.0	2.0	1.3	9.2	2.3/1.5	2.3	0.7			4.7	100.0				Hem(1.0) Mag(0.3)					0.7		0.3	2.7	1.0v			10.3		SA/SA
W/2, 21-6N-6E	0924	945	2.2/2.8	37.0	13.0	3.7	6.8	26.7	2.1/1.7	2.0		0.7	0.7	5.3	100.0				Mag(0.3) Hem(0.3) Epi(0.3) Zir(0.3)		0.7	0.7c		3.0	1.7		0.3		21.7			8.3d[a]	SA/SA
W/2, 21-6N-6E	1065[d]																																
W/2, 21-6N-6E	1128	941	1.3/2.5	32.3	14.7	1.7	5.5	41.1	2.4/1.5	1.7				3.7	100.0				Bio(0.7) Hem(0.3) Epi(0.3)	2.7	1.0		0.7	7.3	0.7	0.3	1.3	2.3s	0.7	1.7		2.6d[a]	SlSS/LSA
W/2, 21-6N-6E	8337	940	2.4/2.4	32.7	15.3	0.3	2.8	35.9	2.5/1.5	1.0	0.3	0.7	0.3	1.3	100.0				Hem(1.0) Mag(0.7) Epi(0.3) Bio(0.3)					1.0			0.7	0.3v	38.0		5.7		SA/SA
W/2, 21-6N-6E	6251	970	2.9/1.7	48.7	22.7	3.0	6.7	10.8	3.1/1.4	1.3	0.3	0.3	0.3	3.7	80.0			20.^	Hem(0.7)					2.7			1.0	0.7s			14.7		SA/SA

			Quartz						Feldspar						Twin Types				Heavy Minerals	Clay Minerals				Rock Fragments					Cements				Rock Name
Location	Thin Section	Elevation (ft.)	$\bar{X}/\bar{\rho}$	MNU	MU	Pxl	Vein (% Qtz)	Overgrown (% Qtz)	$\bar{X}/\bar{\rho}$	Pla	Mic	Per	Ort	Altered or Untwinned	Alb (% Fel)	Car	Alb-Car	Others	Name (%)	Kao	Illite	Mon/Chl	Undefined	GRFs	LmRFs	MRFs	Chert	Others	Calcite	Silica	Clays	Sid/Dol	(McBride/Revised)
NE/4, 32-6N-6E	8241	920	2.2/2.8	32.0	14.3	0.3	2.1	12.9	2.1/1.5	1.7		1.3	0.3	1.3	80.0			20.0	Hem(0.7)				2.7	1.0	5.0		1.0	0.3s	28.0			10.0s	SLSS/SA
SE/4, 1-7N-5E	8062		2.4/2.1	61.0	22.3	2.9	4.3	10.9	2.5/1.9	2.0	0.7		1.3	1.0	83.3			16.7						3.7			1.7	1.3sh			3.0		SA/SA
SE/4, 22-7N-5E	0724		1.2/2.1	21.0	18.7	4.0	11.5	2.3	0.2/2.0	9.0	3.0	0.7	0.3	7.3	89.7	6.9		3.4	Bio(0.3)	0.7	0.3		0.7	7.0			3.3		6.0			17.0s	A/A
SW/4, 9-7N-6E	4281		2.3/2.1	57.3	15.0	5.0	5.6	9.1	2.2/1.3	2.3	0.7	1.3	0.3	4.0	71.4	14.3		14.3	Hem(1.7) Bio(0.3)					2.7			1.7				7.7		SA/SA
SW/4, 9-7N-6E	8366		2.1/2.0	37.7	25.7	2.3	7.6	11.2	2.1/1.9	2.3	0.3	1.0	1.7	3.0	100.0				Bio(0.7) Mag(0.3) Hor(0.3)					3.7	0.3		9.0	1.0^{v}sh			10.7		SA/SA
NW/4, 8-7N-6E	5446		2.2/2.0	57.3	22.0	2.7	4.1	9.8	2.4/1.6	1.3	0.3	0.3	1.0	3.3	100.0				Bio(0.3)	0.3	0.3			2.3			3.0				6.3		SA/SA
SE/4, 2-8N-5E	3969		2.6/1.8	47.3	16.0	2.3	3.6	6.6	2.4/1.7	2.0	0.3	0.3	1.0	4.7	100.0				Epi(1.3) Mag(0.7)	1.3				1.0			1.0		12.0		8.0		SA/SA
NW/4, 35-8N-5E	6787		2.0/1.9	34.0	21.3	2.0	7.0	9.4	1.9/1.7	6.0	1.0	3.3	1.7	6.7	72.2	11.1	5.6	11.1	Bio(1.0)	2.3				10.0			2.3	1.0v			7.3		LSA/LSA
NW/4, 36-8N-5E	8446		2.3/2.2	33.3	16.0	3.3	9.5	19.0	1.9/1.7	5.0	1.0	0.3	0.7	5.3	86.7		13.3		Mag(0.3)		1.0	0.3c	3.0	1.3			4.3		22.7		2.3		SA/SA
E/2, 20-8N-6E	8020		2.8/2.1	41.0	31.3	1.9	5.6	16.1	3.0/1.5	1.0		0.3	0.3	2.9	100.0				Gar(0.6) Epi(0.3) Bio(0.3)	1.0				1.6		0.3	1.3	2.3^{sh}s			13.5		SA/SA
NW/4, 20-8N-6E	4612		2.2/2.1	32.0	10.0	3.0	9.0	5.3	1.9/1.6	3.3	0.7	1.3	0.7	4.7	80.0	10.0		10.0	Hor(0.3)	0.7	1.3			2.0	0.7		3.7		34.7			1.0n	SA/SA
NW/4, 21-8N-6E	8431		2.1/2.3	35.7	22.0	1.7	3.4	14.0	2.3/1.6	3.0	0.7		1.0	2.3	88.9		11.1		Apa(0.3) Hem(0.3)	1.0	1.7			1.7	0.3		1.0		26.0				SA/SA
SW/4, 31-8N-6E	4489		2.3/2.1	44.0	20.3	3.3	5.4	3.4	2.3/1.3	3.3		0.7	1.3	6.0	80.0			20.0	Mag(0.3)	1.7		0.3c		1.7		0.3	2.3				14.3		SA/SA
NE/4, 33-8N-6E	2835		3.1/1.9	43.7	10.0	2.7	2.4	9.5	3.1/1.5	1.3	0.7	0.7		7.7	100.0				Bio(0.3) Epi(0.3)	2.7		0.7c		3.3			3.7		15.7		3.0	2.7^{d}a	SA/SA

Location	Thin Section	Elevation (ft.)	Quartz $\bar{X}/\bar{\sigma}$	Quartz MNU	Quartz MU	Quartz Pxl	Quartz Vein (% Qtz)	Quartz Overgrown (% Qtz)	Feldspar $\bar{X}/\bar{\sigma}$	Feldspar Pla	Feldspar Mic	Feldspar Per	Feldspar Ort	Feldspar Altered or Untwinned	Twin Types Alb (% Fel)	Twin Types Car	Twin Types Alb-Car	Twin Types Others	Heavy Minerals Name (%)	Clay Minerals Kao	Clay Minerals Illite	Clay Minerals Mon/Chl	Clay Minerals Undefined	Rock Fragments CRFs	Rock Fragments LmRFs	Rock Fragments MRFs	Rock Fragments Chert	Rock Fragments Others	Cements Calcite	Cements Silica	Cements Clays	Cements Sid/Dol	Rock Name (McBride/Revised)
SW/4, 13-9N-5E	0646	910	$\frac{2.3}{2.2}$	43.0	18.3	8.3	6.7	20.0	$\frac{2.3}{1.7}$	3.0	0.7			0.7	77.8	11.1	11.1	11.1	Bio(0.3) Mag(0.3) Epi(0.3) Tou(0.3) Hem(0.3)					7.0			5.0	5.0a[b]			6.7		SLSS/SLSS
NW/4, 24-9N-5E	2496		$\frac{1.5}{2.2}$	26.7	14.3	2.7	3.8	5.3	$\frac{1.4}{1.4}$	7.0	1.3	2.0	3.7	10.3	66.7	14.3		19.0	Mag(0.3)	1.3				8.3			10.0				12.0		LA/LA
NW/4, 4-9N-6E	5719	1043	$\frac{1.9}{2.0}$	52.3	22.0	2.7	4.8	3.0	$\frac{2.5}{1.6}$	0.7				2.7	100.0				Hem(0.7)	0.3				0.3			2.3				16.0		QSS/QSS
SW/4, 7-9N-6E	7165	950	$\frac{3.7}{1.8}$	30.9	21.3	0.7			$\frac{3.7}{1.1}$	2.4		0.7		3.1	100.0				Bio(0.7)	2.1		1.4c			0.3		0.7		18.2		17.5		SA/SA
SE/4, 8-9N-6E	8565	960	$\frac{3.2}{2.0}$	35.7	35.0	2.7	4.5	7.7	$\frac{3.2}{1.7}$	1.7	0.3		0.3	7.3	100.0				Epi(0.7) Hem(0.3)	0.3				0.7			2.3	0.3a			12.3		SA/SA
SW/4, 8-10N-6E	4141	930	$\frac{2.7}{2.0}$	56.0	18.0	3.3	4.3	5.6	$\frac{2.8}{1.5}$	1.3			0.7	5.7	100.0				Bio(0.7) Mag(0.3) Rut(0.3) Epi(0.3)	1.0				2.0			2.3				8.0		SA/SA
SW/4, 9-10N-6E	1798	930	$\frac{2.4}{2.0}$	58.3	15.0	4.7	6.8	6.4	$\frac{1.7}{2.1}$	0.3			0.3	5.3	100.0				Epi(0.3) Ilm(0.3)	5.7							0.7	0.7a			8.3		SLSS/SA
NE/4, 20-10N-6E	0941	945	$\frac{2.3}{2.2}$	41.9	37.0	4.8	4.5	0.8	$\frac{2.2}{1.5}$	1.0				1.4	100.0									1.7		0.7	1.0				10.0		QSS/QSS
NW/4, 28-10N-6E	3385	958	$\frac{1.8}{2.2}$	62.1	19.1	4.1	8.4	33.6	$\frac{1.9}{1.3}$	1.4			1.4	1.7	75.0			25.0		1.0				3.1		0.3	3.4				2.4		QSS/SA
NW/4, 33-11N-6E	6510	970	$\frac{3.0}{1.8}$	44.0	16.3	4.0	2.6	4.1	$\frac{2.9}{1.6}$	1.7			0.3	5.7	100.0				Bio(0.3) Mag(0.3)	2.0							1.0	0.3a			24.3		SA/SA
SW/4, 33-11N-6E	4029	960	$\frac{2.4}{1.9}$	58.3	17.7	3.0	2.1	6.3	$\frac{2.4}{1.8}$	0.3	0.3		0.3	3.7	100.0				Bio(0.3) Mag(0.3)	0.7				0.7			2.7				11.3		SA/SA
NW/4, 3-1S-2W	0631[e]																																

[a]quartzose intrasparite
[b]dismicrite
[c]arkosic microsparite
[d]Poor thin-section, not counted
[e]Sample of float, not analyzed

APPENDIX B

SUBSURFACE CORE DATA

Cores on file at the Oklahoma Core and Sample Library in Norman, Oklahoma were also available for study by the writer. One set of cores from a feasibility study done for the Air Force (contract W. S. 133-A) included a small portion of the dissertation research area. Three sample locations; sites 102, 142 and 245, penetrated Vanoss rocks in the research area and are briefly described below. Results are of dubious value because the locations are given as general mileage and direction from Tinker Air Force Base in Midwest City, Oklahoma plus distance from the nearest community.

Site #102--Southwest Seminole County in Highway 99; 2 miles southeast of Konawa and 50 miles southeast of Tinker Air Force Base.

3 samples: #1--Shale at depth of 59 feet; arkosic.

#2--Arkosic sandstone at 51 feet; gray-green.

#3--Arkosic sandstone at 66 feet; red-brown (sample thin-section #5102-S).

Site #142--Five miles southeast of Stratford; spud in basal "Hart."

2 samples: #1--Shale at 49 feet; gray.

#2--Shale at 44 feet; red and feldspathic.

(location vague, elevations unknown) sample thin-section #5142.

Site #245--Eight miles southwest of Ada, 58 miles southeast of Tinker on low-relief feature. Reportedly topped Vanoss at 50 feet but conglomerate (arkosic) at 30 feet.

2 samples: #1--Sandstone, arkosic at 72 feet (sample thin-section #5245).

#2--Shale, arkosic.

Thin-sections were evaluated for presence or absence of cutan, degree of alteration of the feldspars, if present and gross mineralogy. Samples were collected from portions of each core identified as "Vanoss" by the drillers.

APPENDIX C

RELATIVE ABUNDANCES--CLAYS

Sample Number	Location	Kao-linite	Mont-moril-lonite	Illite	Chlorite
76	SE NW 8-1S-1W	2.00	--	--	--
30	E/2 SE and NE, 3-1S-1W	0.80(tr)	--	--	--
45	SE SE NE, 10-1S-1E	2.55	--	--	--
26	SE SE, 2-1S-1E	(tr)	--	--	--
41	SW NE, 19-1S-2E	8.00	--	--	--
44	C SE, 17-1S-2E	(tr)			
51	C NE edge, 14-1S-2E	23.65	--	(tr?)	--
35	SW SE, 5-1S-2E	12.20	--	(tr?)	--
54	NW NE NW, 3-1S-2E	6.60	3.36	--	--
25	NW NE NW, 3-1S-2E	18.28	1.98	(tr)	--
57	E center SE, 30-1S-3E	3.60	--	(tr?)	--
45	SW NW, 28-1S-3E	1.90(est)	--	1.50(est)	--
101	SE SE, 16-1S-3E	3.36	--	--	--
12	SW SE, 15-1S-3E	7.00	--	3.80	--
42	NE SE, 11-1S-3E	10.20	--	(tr)	--
71	SW NW, 10-1S-3E	33.30	2.8	--	--
46	NE NW SW, 10-1S-3E	10.48	(tr)	6.0(ki)	2

12	SW SW SE, 5-1S-3E	37.50	--	(tr)	--
36	SE NW, 2-1S-3E	35.50	--	3.0	--
19	SW NE, 1-1S-3E	27.12	--	(tr)	--
68	NE SW, 1-1S-3E	32.40	--	1.28	--
38	NE NW SE, 36-1N-3E	47.19	--	3.60	--
39	NE NW SE, 36-1N-3E	33.00	--	1.80	--
29	SE SE and SE, 26-1N-3E	13.20	--	(tr?)	--
33	SE SW, 25-1N-3E	19.50	--	--	--
23	SE NE, 25-1N-3E	32.76	--	(tr?)	--
52	SW NW, 30-1N-4E	21.75	--	(tr?)	--
63	SW NW, 30-1N-4E	15.60	--	--	--
97	SW NW, 30-1N-4E	22.00	--	--	--
77	SW NW, 30-1N-4E	15.00	--	(tr?)	--
44	SW NW, 30-1N-4E	22.05	--	--	--
27	SW, 32-2N-4E	34.00	--	2.88	--
35	SW NE, 30-2N-4E	19.20	--	(tr?)	--
53	SW SE, 21-2N-4E	55.00	--	3.00	--
18	SW SW, 20-2N-4E	34.40	--	--	--
46	SW SE NE, 14-2N-4E	8.60	--	--	--
39	NW NW, 12-2N-4E	80.10	--	(tr)	--
29	SE SE, 10-2N-4E	63.60	--	2.12	--
58	SW NE, 10-2N-4E	50.00	--	(tr?)	--
55	C NW, 6-2N-5E N or E	26.04	--	--	--
40	NE NE, 6-2N-4E	--	--	--	12.00
48	NE SW, 3-2N-4E	18.00	--	--	--
61	NE NE, 3-2N-4E	65.00	--	--	--

84	SE SW SE, 34-3N-4E	55.20	1.50	1.80	--
104	NW, 33-3N-4E	5.20	8.75?	--	--
96	NW, 33-3N-4E	6.00	48.00	--	--
102	Edge Midline 18-3N-4E	5.10	(tr?)	(tr)	--
2	SW SE SW, 12-3N-4E	72.00	--	--	--
10	SW SW NW, 9-3N-4E	18.00	12.32	(tr?)	--
8	SW SW NW, 9-3N-4E	1.05	19.00	8.80	--
15	NE SW NE, 5-3N-4E	(tr?)	(tr?)	(tr?)	--
86	NE SW NE, 5-3N-4E	9.93	15.50	13.20	--
89	SE NW, 4-3N-4E	14.72	8.00?	--	--
72	NE NE, 3-3N-4E	8.15	(tr?)	--	--
143	SW, 2-3N-4E	3.00	--	--	--
29	SE SE, 2-3N-4E	15.30	--	--	--
133	NW NW, 7-3N-5E	21.75	--	--	--
9	NE, 6-3N-5E #1	21.60	--	(tr?)	--
11	NE, 6-3N-SE #2	42.60	--	(tr?)	--
107	SW NW SE, 35-4N-4E	1.26	3.50	(tr?)	--
27	NE SE, 34-4N-4E	18.20	1.20	(tr?)	--
28	SW NW SE, 29-4N-4E	(tr?)	(tr?)	--	--
100	C W/2, 27-4N-4E	1.14			
103	C W/2, 27-4N-4E	43.25	(tr?)	(tr?)	--
111	C W/2, 27-4N-4E	10.48	8.10	3.48	--
113	SE SE, 26-4N-4E	2.01	52.00	(tr?)	--
147	SE SW, 23-4N-4E	1.50	(tr?)	--	--
99	C N/2 SE, 19-4N-4E	4.08	--	--	2.48
6	SE, 13-4N-4E	28.50(est)	--	--	(tr?)

92	NE, 13-4N-4E	37.50	--	--	--
24	SW SW, 11-4N-4E	4.40	--	--	--
20	SW SW, 11-4N-4E	9.00	1.30?	2.70	--
56	NE NW, 11-4N-4E	2.82	--	--	--
69	NE NW, 11-4N-4E	9.90	(tr?)	2.56	--
22	NW NE NW, 1-4N-4E	14.80	--	--	--
3	S/2, 1-4N-4E	90.00	--	--	--
5	SW NW SE, 31-4N-5E	34.40	9.0	23.40	--
116	C SW, 34-5N-4E	24.50		--	--
60	N/2, 16-5N-4E	30.50	42.00	--	--
19	N/2, 16-5N-4E	57.60	(tr)	(tr?)	--
105	N/2, 16-5N-4E	46.50	9.60	(tr?)	--
31	NE NW, 13-5N-4E	10.80	--	(tr?)	--
82	SE, 10-5N-4E	108.00	--	(tr?)	--
93	NE SW, 7-5N-4E	1.00	--	1.48	--
79	NE NE, 21-5N-5E	2.07	--	--	--
91	SE SE, 13-5N-5E (?6N)	25.28	(tr?)	(tr?)	--
33	NW SW, 12-5N-5E	39.20	(tr?)	(tr)	--
132	NW SW, 12-5N-5E	12.74	2.60	2.68	--
90	NE SE NE, 10-5N-5E	57.60	(tr?)	2.44	--
26	NE SE NE, 10-5N-5E	26.40	(tr?)	(tr?)	(tr?)
83	SW, 9-5N-5E	80.00	--	(tr?)	--
94	NE SE, 2-5N-5E	65.10	(tr?)	(tr)	(tr?)
30	SE NW, 5-5N-6E	13.80	--	--	(tr?)
21	SE NW, 5-5N-6E	61.74	(tr?)	(tr?)	(tr?)
122	N/2, 5-5N-6E	4.05	--	--	--

13	SE SW, 36-6N-5E	38.40	--	(tr?)	--
1	SE NE, 13-6N-5E	(19 est)	(tr?)	3.80(est)	--
17	SW SE, 12-6N-5E	16.50(est)	(tr?)	(tr?)	--
95	SE SE, 10-6N-5E	21.40	--	2.00	--
80	SE SE, 10-6N-5E	38.40	1.38	6.10	--
4	SE SE, 10-6N-5E	(tr)	?	(tr)	?
43	NE, 4-6N-5E	16.00	--	(tr?)	--
65	SE SW, 3-6N-5E	46.10	(tr)	3.30	--
38	NW NW, 1-6N-5E	8.04	--	(tr?)	--
32	NW NW, 1-6N-5E	5.60	(tr?)	1.40	--
134	NE NE, 32-6N-6E	45.00	--	--	--
7	SE, 31-6N-6E	26.64	--	(tr?)	--
110	W/2, 21-6N-6E	10.50			
108	W/2, 21-6N-6E	42.50	--	--	--
81	NW NE, 6-6N-6E	21.60	--	(tr?)	--
142	NW, 5-6N-6E	27.54	(tr?)	(tr?)	--
124	SW SE, 22-7N-5E	31.05	--	--	--
123	SW SE, 22-7N-5E	25.02	5.50	2.80	
62	SE SE, 1-7N-5E	90.18	(tr?)	1.26	--
117	NE SW, 9-7N-6E	32.65	--	3.60	--
114	NE SW, 9-7N-6E	14.60	--	1.12	--
131	NE NW, 8-7N-6E	30.00	(tr?)	(tr?)	--
14	E/2, NW, 36-8N-5E	16.14	--	--	--
16	E/2, NW, 36-8N-5E	9.00	(tr?)	(tr?)	(tr?)
87	NE NW, 35-8N-5E	37.24	--	--	--
109	SE SE, 2-8N-5E	15.75	--	--	--

115	SE SE, 2-8N-5E	18.25	(tr)	2.52	--
74	NW NE, 33-8N-6E	33.60	(tr)	(tr)	--
137	SW SW, 31-8N-6E	38.40	1.24	(tr)	--
136	SW SW, 31-8N-6E	9.90	2.80	1.80	--
106	NW, 21-8N-6E	21.69	--	--	--
85	NW NW, 20-8N-6E	11.10	(tr)	(tr)	--
88	NW NW, 20-8N-6E	11.75	(tr?)	(tr?)	--
66	E/2, 17-8N-6E	33.68	--	1.80	--
75	E/2, 17-8N-6E	25.20	--	(tr)	--
120	S/2, NW, 24-9N-5E	30.72	--	--	--
78	SE, 13-9N-5E	38.40	(tr)	1.41	--
67	SE, 13-9N-5E	22.86	(tr)	1.60	--
34	SW SE, 8-9N-6E	17.52	(tr?)	(tr)	--
49	SE SW, 7-9N-6E	14.80	--	--	--
50	SE SW, 7-9N-6E	14.69	--	--	--
47	NE NW, 4-9N-6E	18.24	3.00	1.38	--
59	NW NW, 28-10N-6E	49.68	(tr)	1.16	--
70	NW NW, 28-10N-6E	19.20	(tr)	1.96	--
40	N/2, 20-10N-6E	57.54	6.63	1.55	--
64	SW SE, 9-10N-6E	12.18	--	(tr?)	--
73	SW SW, 8-10N-6E	36.56	--	(tr?)	--
118	SW, 33-11N-6E	12.30	--	--	--
41	NW NW, 33-11N-6E	57.60	--	(tr?)	--
37	NE NW, 33-11N-6E	28.26	(tr)	(tr)	--

Values = Peak Intensity x 1/2 peak width
(tr?) = too small to measure
(tr) = 1
-- = not present

APPENDIX D

INDEX TO COLLECTION LOCALITIES

(Numbers in first column correspond to those on Plate V in pocket.)

Number	Thin-Section Number	Description
1.	7057	NW 1/4 SW 1/4 Sec. 7, T. 2 S., R. 5 E.; collected from grus in dry stream bed on west side of Century Granite Quarry in Troy granite. Approximately 300 feet west of compressor house.
2.	3435	NE 1/4 NE 1/4, Sec. 3, T. 1 S., R. 1 W.; collected from northeast corner of Hennipin and 1.1 miles south of Oklahoma Route 7.
3.	8614	N 1/2 Sec. 8, T. 1 S., R. 1 W.; sample collected on west side of minor divide between two small streams (west stream) north of county road 2.2 miles southeast of Hennepin.
4.	8299	SE 1/4 SE 1/4, Sec. 2, T. 1 S., R. 1 E.; sample collected from south side of access road to quarry off of county road 2 miles southwest of Davis and 0.2 miles west of Oklahoma Route 77D.
5.	9675	SE 1/4 SE 1/4 NE 1/4 Sec. 10, T. 1 S., R. 1 E.; sample collected on west side of county road bar ditch (trenched) approximately 1.3 miles south of Oklahoma Route 7.

6.	1538	NW 1/4 NE 1/4 NW 1/4 Sec. 3, T. 1 S., R. 2 E.; sample collected from slope on west side of farm pond about 800 feet south of barn (trenched) 1.4 miles east of Davis and 0.2 miles south of Oklahoma Route 7.
7.	8594	NE 1/4 NE 1/4 NW 1/4 Sec. 3, T. 1 S., R. 2 E.; sample taken from roadcut on the south side of Oklahoma Route 7 approximately 0.15 miles west of Thomas Brothers' Grocery and 1.4 miles east of Davis.
8.	9861	SW 1/4 SE 1/4 Sec. 5 T. 1 S., R. 3 E.; sample taken from large float blocks pried loose by farmer and stacked on west side of county road 1 mile south of Oklahoma Route 7 entering Arbuckle Lake Park from the east side.
9.	4753	SW 1/4 SW 1/4 SE 1/4, Sec. 5 T. 1 S., R. 2 E.; sample of feldspathic sandstone approximately 0.2 miles west of #9 but on north side of road.
10.	5516	NE edge, Sec. 14, T. 1 S., R. 2 E.; collected on the approximate edge of section 20 feet to the east of tri-angulation point, elevation 1023.46 feet.
11.	9688	NE 1/4 SE 1/4, Sec. 17, T. 1 S., R. 2 E.; sample taken on east side of railroad cut 800 feet north of railroad (AT and SF) crossing. Attitude, N80W; 10NE.
12.	2485	SW 1/4 NE 1/4, Sec. 19, T. 1 S., R. 3 E.; collected from road cut approximately 0.1 miles south of Arbuckle Trading Post on access road to Lake of the Arbuckles.
13.	2041	SW 1/4 NE 1/4, Sec. 1, T. 1 S., R. 3 E.; sample collected from outcrop approximately midway between two roadways on eastern portion of Platt National Park.

14.	9452	NE 1/4 SW 1/4, Sec. 1, T. 1 S., R. 3 E.; sample collected from digging 900-1000 feet west of corner of fence line 3800 feet west and 1800 feet north of elevation 1127 (on quadrangle map)
15.	6808	SE 1/4 NW 1/4, Sec. 2, T. 1 S., R. 3 E.; collected approximately 0.7 mile east of Oklahoma route 18 on looping access road 35 feet above the stream and randomly chosen from the hillside which is all Vanoss conglomeratic sandstone.
16.	5821	NE 1/4 NW 1/4 SW 1/4, Sec. 10, T. 1 S., R. 3 E.; collected from shallow trench about 250 feet due west of end of jeep trail south of Veteran's Lake.
17.	8100	NE 1/4 SE 1/4, Sec. 11, T. 1 S., R. 3 E.; sample collected from wall of drainage ditch along road to Veteran's hospital 2600 feet north of intersection of junction between two hard-surfaced roads at elevation 1135 feet.
18.	7588	SW 1/4 SE 1/4, Sec. 15, T. 1 S., R. 3 E.; from east side of filled quarry (abandoned) about 700 feet north of county road.
19.	9576	SE 1/4 SE 1/4, Sec. 16, T. 1 S., R. 3 E.; sample collected in trench dug in minor gully running northwest from SE corner of section approximately 400 feet west of quarry and 700 feet north of ranch road.
20.	4623	SW 1/4 NW 1/4, Sec. 28, T. 1 S., R. 3 E.; taken from small trench dug 600 feet due north along creek from county road and at the 1/2 section fence line.
21.	9080	East of center SE 1/4, Sec. 30, T. 1 S., R. 3 E.; sample collected 800 feet northeast of state route 110 above the Arbuckle Lake dam at triangulation point (elevation 964 feet).

22.	0824	SE 1/4 SE 1/4 SW 1/4, Sec. 25, T. 1 N., R. 3 E.; sample collected 200 feet north of road and 100 feet west of pond on half-section fence where thin ledges protrude.
23.	5949	SE 1/4 SE 1/4 NE 1/4, Sec. 25, T. 1 N., R. 3 E.; taken from a trench dug in a slope in a stream gully 300 feet west of county road leading to pond in abandoned gravel pit.
24.	7915 & 1677	C SE 1/4 SE 1/4 SE 1/4, Sec. 26, T. 1 N., R. 3 E.; collected from area of field scraped by tractor, along crest of ridge trending N 50 W and 1000 feet from right angle turn in county road (elevation 1093).
25.	4290	Same locations as two above but 1600 feet in a direction N 50 W from the intersection.
26.	9715, 9840, 8930, 5005, & 3175	SW 1/4 NW 1/4, Sec. 30, T. 1 N., R. 4 E.; samples collected from abandoned gravel pit which encompasses entire eighth of section; sampled from bottom to top, thin-sections are of units 1,2,3,5 and 6, unit 4 is a coarse conglomerate (cobbles) free of finer matrix.
27.	4262 & 1605	NE 1/4 NW 1/4 SE 1/4, Sec. 36, T. 1 N., R. 3 E.; two samples collected from a bare slope between two streamlets 150 feet south of county road and approximately 1000 feet north of Oklahoma Route 7.
28.	6616	C NW 1/4, Sec. 6, T. 2 N., R. 5 E.; sample taken from trench in continuous outcrop band 3 miles northwest of Fitzhugh along stream 1200 feet southeast of county road intersection with elevation 1169 feet.

29.	6832	NE 1/4 NE 1/4, Sec. 3, T. 2 N., R. 4 E.; located about 500 feet south of county road and 1.3 miles west of intersection with Oklahoma highway 61, sample was taken at the crest of a broad ridge.
30.	0752	NE 1/4 SW 1/4, Sec. 3, T. 2 N., R. 4 E.; taken from trench on northern slope of ridge, sample is 500 feet south and 50 feet west of bridge (elevation 1097 feet) on county road 1.5 miles west of Oklahoma Route 61. Attitude of beds highly varied N 60-80 E; 0-17 NW.
31.	2266	NE 1/4 NE 1/4, Sec. 6, T. 2 N., R. 4 E.; sample collected from nose of hill about 100 feet below abandoned house and 200 feet south of county road; elevation from intersection (elevation 1114 feet).
32.	8515	NW 1/4 SW 1/4 NE 1/4, Sec. 10, T. 2 N., R. 4 E.; sample collected from upper 1/4 of ridge, 1.4 miles south of intersection of county roads on fork of Canadian Sandy Creek.
33.	5575	SE SE, Sec. 10, T. 2 N., R. 4 E.; sample collected 1400 feet east and 300 feet north along fence line from county road; elevation from bench mark 1239 feet.
34.	4456	SW 1/4 SE 1/4 NE 1/4, Sec. 14, T. 2 N., R. 4 E.; sample collected from shallow borrow pit dug by Mr. Box 400 feet west of state highway 61, 1.2 miles north of intersection of 61 and Oklahoma Route 12 in Roff, Oklahoma.
35.	9162	SW 1/4 SW 1/4, Sec. 20, T. 2 N., R. 4 E.; sample collected from trench dug about 200 feet north of asphalt road and 200 feet east of Dolberg Church.

36.	4693	SW 1/4 SE 1/4, Sec. 21, T. 2 N., R. 4 E.; sample collected from shallow trench dug into south end of ridge, 2.5 miles west of Roff on un-numbered hard-surface road.
37.	8488	SW 1/4 NE 1/4, Sec. 30, T. 2 N., R. 4 E.; sample collected from trench dug in stream bank immediately down hill from stock pond approximately 0.5 miles south of asphalt road and Dolberg Church.
38.	6980	SW 1/4, Sec. 32, T. 2 N., R. 4 E.; sample collected from base of change in slope midway up south face of Chickasaw Hill, 0.3 miles north of county line road and chicken ranch.
39.	1316	SE 1/4 SE 1/4, Sec. 2, T. 3 N., R. 4 E.; sample collected from shallow trench on northeast side of dry gully trending northwest from the section corner 1000 feet southeast.
40.	5336	SE 1/4 SW 1/4, Sec. 2, T. 3 N., R. 4 E.; sample collected about 1.4 miles southeast of Vanoss, Oklahoma on the crest of hill about 90 feet north of county road where it turns to southwest.
41.	4095	NE 1/4 NE 1/4, Sec. 3, T. 3 N., R. 4 E.; collected from slopes of ridge approximately 300 yards south of Burris Creek and 100 yards south of Oklahoma Route 61 at point where it turns north.
42.	4286	SE 1/4 NW 1/4, Sec. 4, T. 3 N., R. 4 E.; collected from stream bed less than 100 feet north of pond and 2500 feet southeast of northwest corner of section.
43.	7434 & 7435	NE 1/4 SW 1/4 NE 1/4, Sec. 5, T. 3 N., R. 4 E.; located about 1100 feet southwest of AT and SF tracks and 100 feet north of farmhouse on north side of road through half section.

44.	8681	SW 1/4 SW 1/4 NW 1/4, Sec. 9, T. 3 N., R. 4 E.; sample of outcrop of flaggy sandstone deeply weathered and in bar ditch 30 feet south of Sun Oil pipeline and about 0.3 miles north of point where Coon Creek crosses county road.
45.	8517	SW 1/4 SE 1/4 SW 1/4, Sec. 12, T. 3 N., R. 4 E.; collected from 10 feet below crest of ridge directly north of house 0.38 mile east of intersection of medium duty road and Oklahoma Route 61.
46.	3376	NE 1/4 NW 1/4, Sec. 17, T. 3 N., R. 4 E.; sample is a white micritic limestone capping the north-south ridge and collected from small ledge 250 feet south of county road where it turns north at elevation 1095 feet.
47.	8161	Approximate midpoint along east line, Sec. 18, T. 3 N., R. 4 E.; sample collected 220 feet west of county road and 500 feet northeast of spillway and location is directly across road from fenceline at midpoint of section 17.
48.	9513 & 5111	SE 1/4 SE 1/4 SE 1/4, Sec. 31, T. 3 N., R. 4 E.; sample collected 500 feet northwest of intersection with elevation of 1114 feet, 0.9 mile east of county line.
49.	8354, 2764, 9189, & 0439	C NW 1/4 NW 1/4, Sec. 33, T. 3 N., R. 4 E.; sample collected from bare slope of possible abandoned drilling site, 4.3 miles east of U.S. Route 177, 650 feet southeast of northwest corner of section where two county roads intersect.
50.	1342	SE 1/4 SW 1/4 SE 1/4, Sec. 34, T. 3 N., R. 4 E.; location is 5.6 miles east of U.S. 177 and 0.15 mile east of the intersection of two county roads (elevation 1157 feet); sampled from trench in bare portion of slope.

51.	0033, 5855, 0521, & 0112	E 1/2, SE 1/4 NE 1/4, Sec. 6, T. 3 N., R. 5 E.; located 0.6 mile south of AT and SF railroad tracks, 200 feet west of road 900 feet north of fence line, leveled from bridge (elevation 998 feet).
52.	6708	NW 1/4 NW 1/4, Sec. 7, T. 3 N., R. 5 E.; approximately 2500 feet S45E from the northwest corner of section, sample collected from trench midslope.
53.	8482	NW 1/4 NE 1/4 NW 1/4, Sec. 1, T. 4 N., R. 4 E; sample location is 1000 feet east of road and about 350 feet south of stock pond and fork of Spring Brook Creek.
54.	0001	C S 1/2, Sec. 1, T. 4 N., R. 4 E.; sample collected on first "bench" below ridge crest along fence line 600 feet north of county road and 1.2 miles southwest of the Freewill Baptist Church.
55.	6415	NE 1/4 NW 1/4, Sec. 11, T. 4 N., R. 4 E.; collected from point 300 feet south of road and about 400 feet west of centerline; interbedded with red-gray shale sampled for heavy minerals.
56.	1767	SW 1/4 SW 1/4, Sec. 11, T. 4 N., R. 4 E.; located 0.25 mile north of intersection of two county roads and about 2.3 miles north of Gaar Corner, behind second house from the south line (in section).
57.	7731	C E 1/2 SE 1/4, Sec. 13, T. 4 N., R. 4 E.; sample is about 1500 feet south-southwest of house at top of flat area off of county road approximately 500 feet away.
58.	2147	NW 1/4 SE 1/4 NE 1/4, Sec. 13, T. 4 N., R. 4 E.; location is about 1500 feet north of house on low ridge cut by sluggish stream. Outcrops of small ledges but trenched to ensure fresh sample.

59.	1295	C W 1/2 SE 1/4 NE 1/4, Sec. 19, T. 4 N., R. 4 E.; sample collected from deep trench cut on midslope from farm pond at head of stream beginning in SE 1/4 NE 1/4 of section.
60.	5282	SE 1/4 SW 1/4, Sec. 23, T. 4 N., R. 4 E.; 550 feet north of Oklahoma Route 19 and 0.33 mile east of Gaar Corner.
61.	8804, 3740	C W 1/2, Sec. 27, T. 4 N., R. 4 E.; both samples collected 0.5 mile south of Oklahoma Route 19 and intersection with county road 1 mile west of Gaar Corner.
62.	3711	SW 1/4 NW 1/4 SE 1/4, Sec. 29, T. 4 N., R. 4 E.; sample location is 450 feet behind house, 550 feet from county road (to the west of site) and 0.75 mile south of Oklahoma Route 19, 250 feet south of farm pond.
63.	7599	NE 1/4 SE 1/4, Sec. 34, T. 4 N., R. 4 E.; this location is from a trench dug 200 feet west of Oklahoma Route 61, 0.3 mile north of the south boundary line of the section and about 1.1 miles from Vanoss general store.
64.	4387	SW 1/4 NW 1/4 SE 1/4, Sec. 35, T. 4 N., R. 4 E.; sample scraped out of stream bed 500 feet north (upstream) from AT & SF tracks.
65.	6689	SW 1/4 NW 1/4 SE 1/4, Sec. 31, T. 4 N., R. 5 E.; sample from deep trench 1.8 miles south of Center, Oklahoma, near middle of section, 2300 feet northwest of railroad track crossing on county road.
66.	0364	NE 1/4 SW 1/4, Sec. 7, T. 5 N., R. 4 E.; the sample was collected from an erosional gully east of the road 0.25 mile northwest of intersection of Oklahoma Route 13 and county road about 0.4 mile south of Big Creek.

67.	8520, 4075, & 6944	N 1/2, Sec. 16, T. 5 N., R. 4 E.; 2.3 miles east of intersection of county road and Oklahoma Route 13, this sample is 100 to 300 feet (continuously exposed) east of intersection of two county roads.
68.	9832	NE 1/4 SW 1/4 SE 1/4, Sec. 10, T. 5 N., R. 4 E.; located about 3.5 miles west of Oklahoma Route 13, about 1 mile south of Canadian River and 400 feet southeast of small stream bed. Attitude is N62W;4NE.
69.	9407	NE 1/4 NW 1/4, Sec. 13, T. 5 N., R. 4 E.; sample collected 200 feet west of abandoned well and jeep trail, about 6 miles west of Oklahoma Route 13.
70.	1247	C SW 1/4, Sec. 34, T. 5 N., R. 4 E.; sample collected on hill close to stream behind house on fork to Spring Creek 1.6 miles south of the intersection of Oklahoma Routes 61 and 13.
71.	5382	NE 1/4 NE 1/4 SE 1/4, Sec. 2, T. 5 N., R. 5 E.; located at south end of ridge crest, 430 feet west of county road and 1.5 miles south of medium duty road at southeast end of Konawa, Oklahoma.
72.	0088	SW 1/4, Sec. 9, T. 5 N., R. 5 E.; sample is 20 feet lower in elevation than base of house, 0.2 miles south of first bend in county road 3.25 miles from Konawa. Attitude is N5W to N2E;0-1W.
73.	3868	NE 1/4 SE 1/4 NE 1/4, Sec. 10, T. 5 N., R. 5 E.; collected from a trench dug in a ridge 0.25 mile south of Grayson Church at a point of a ridge 300 feet west of a county road and 2.25 miles south, southwest of Konawa.

74.	3875	NW 1/4 SW 1/4, Sec. 12, T. 5 N., R. 5 E.; thin stringers of arkosic sandstone located 2.5 miles south, southeast of Konawa on flat area southeast of house 0.2 mile south of Oklahoma City, Ada, Atoka railroad tracks as pass near Bench Mark with elevation of 877 feet.
75.	8768, 5689	C SE 1/4 NW 1/4, Sec. 5, T. 5 N., R. 6 E.; with sample 8768 20 feet, higher stratigraphically than 5689, both were collected from ridge 1700 feet southeast of jeep trail trending southeast from Oklahoma Routes 3 and 99 approximately 3 miles southeast of Konawa.
76.	6590, 1885	SW 1/4 SE 1/4 NE 1/4, Sec. 5, T. 5 N., R. 6 E.; samples collected approximately 5000 feet west of Oklahoma Routes 3 and 99 as they bend southward. Irregular outcrops about 80-90 feet above the Canadian River floodplain.
77.	6114	NE 1/4 NE 1/4, Sec. 21, T. 5 N., R. 6 E.; collected 3.1 miles south of South Fork of Canadian River where pointbar is developed and from a ridge which crops out in the drainage ditch to the east of Oklahoma Route 99.
78.	8995	NW 1/4 NW 1/4, Sec. 1, T. 6 N., R. 5 E.; sample collected from bar ditch directly in front of house (east of ditch). Estimated elevation is 970 feet.
79.	6617	SE 1/4 SW 1/4, Sec. 3, T. 6 N., R. 5 E.; location is in bar ditch (north side of county road) 0.3 mile east of county line, approximately 0.1 mile west of house.
80.	2988 & 1080	SE 1/4 SE 1/4, Sec. 10, T. 6 N., R. 5 E.; located 2.6 miles north of Konawa on first medium-duty road east of town and intersecting with Oklahoma Route 39. Sequence exposed in faces of scraped area at highway intersection but samples from trenching northwest of scraped area.

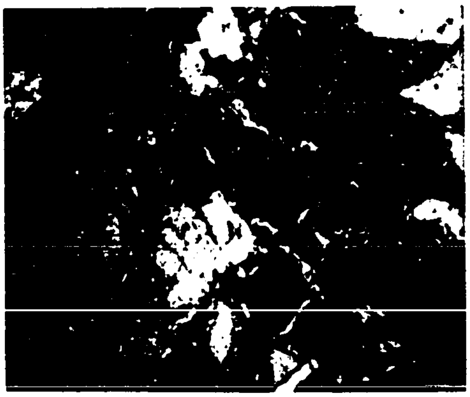
81.	2065	SW 1/4 SE 1/4, Sec. 12, T. 6 N., R. 5 E.; sample collected from south end of ridge trending north-south about 1.0 mile west of the intersection of Oklahoma Routes 3 and 99 with county road between sections 12 and 13.
82.	8771	SE 1/4 NE 1/4, Sec. 13, T. 6 N., R. 5 E.; sample taken from trench 0.75 mile north of High Spring Church about 8 feet above elevation of county road at nose of small ridge trending southeast.
83.	6712	SE 1/4 SE 1/4, Sec. 36, T. 6 N., R. 5 E.; located 200 feet from end of stream flowing to the northeast under Oklahoma Routes 3 and 99 and about 1000 feet due north of section line road and 700 feet east of farm pond in southeast quarter of southwest section.
84.	4992	C NW 1/4, Sec. 5, T. 6 N., R. 6 E.; sample collected from shallow trench in bank of farm pond about 300 feet north of fence line through middle of quarter, 3 miles north and 0.5 mile east of High Spring Church.
85.	5565	NW 1/4 NE 1/4, Sec. 6, T. 6 N., R. 6 E.; location of sample is patch of Vanoss exposed in bed of small stream flowing northwest approximately 500 feet upstream from county road and 1.5 miles west of intersection with Oklahoma Routes 3 and 99.
86.	0924, 1065, 1128, 8337, & 6251	Approximately center of W 1/2, Sec. 21, T. 6 N., R. 6 E.; samples were collected from the slopes at the head of a small stream 0.5 mile southwest of Vamoosa and actually following northwest gully to minor divide. Sampling begun approximately 200 feet north of farm pond.

87.	8241	NE 1/4 NE 1/4, Sec. 32, T. 6 N., R. 6 E.; located on southeast side of gently sloping hill 300 feet east of jeep trail and 950 feet south of county roads intersecting at elevation of 961 feet.
88.	8062	SE 1/4 SE 1/4, Sec. 1, T. 7 N., R. 5 E.; part of an apparent deltaic sequence dipping about N20W (?), sample was collected from trench dug about 80 feet north of small farm pond in head waters of small stream and about 0.2 mile west of the southeast section corner.
89.	0724	SW 1/4 SE 1/4, Sec. 22, T. 7 N., R. 5 E.; sample collected from trench dug between house and county road, north of the east-west road and 8 miles north of Konawa.
90.	5446	NE 1/4 NW 1/4, Sec. 8, T. 7 N., R. 6 E.; the sample was collected 50 feet south of well on side of possible old borrow pit which is about 700 feet south of county road. Location difficult to pinpoint due to few markers.
91.	4281 & 8366	NE 1/4 SW 1/4, Sec. 9, T. 7 N., R. 6 E.; location is near center of quarter of quarter section at headwaters of small stream flowing southwest where bare slope is easily trenched.
92.	3969	SE 1/4 SE 1/4, Sec. 2, T. 8 N., R. 5 E.; located 250 feet from county road (north-south orientation) and about 300 feet due east of fork in jeep trails to wells, sample was collected from a flattened area after minor trenching.
93.	6787	NE 1/4 NW 1/4, Sec. 35, T. 8 N., R. 5 E.; sample collected from a ridge south of the eastward extension of Oklahoma Route 59 less than 1 mile east of Maud, Oklahoma. Faults of small displacement evident trending about N 15 W.

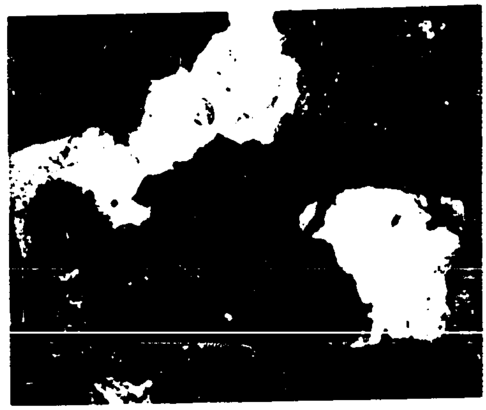
94.	8446	E 1/2 NW 1/4, Sec. 36, T. 8 N., R. 5 E.; location of sample is 0.25 mile beyond northwest section corner, 100 feet south of the road (extention of Oklahoma Route 59).
95.	8020	E 1/2 (continuous), Sec. 17, T. 8 N., R. 6 E.; sample taken from bedrock outcrop along west side of road (as in Section 20, also), 1 mile north and 1 mile west of Bowlegs, Oklahoma. Unusual contorted bedding and significant amounts of chert present.
96.	4612	NW 1/4 NW 1/4, Sec. 20, T. 8 N., R. 6 E.; about 2 miles west and .75 mile north of Bowlegs, sample was collected of sandstone cropping out along dry stream bed flowing south-southwest.
97.	8431	C NW 1/4, Sec. 21, T. 8 N., R. 6 E.; sample collected from trench dug in top of ridge 200 feet behind a house at the end of a jeep road toward a small stream.
98.	4489	SW 1/4 SW 1/4, Sec. 31, T. 8 N., R. 6 E.; the sample was collected from the deltaic sequence exposed 1 mile south and 3 miles east of Maud, 500 feet east of southwest corner of section.
99.	2835	C NE 1/4, Sec. 33, T. 8 N., R. 6 E.; sample collected from steep slope between two tributaries to Little River about 1.3 miles south of Bowlegs and 2500 feet southeast of intersection of Oklahoma Routes 3 and 99 with east-west county road between sections 33 and 28.
100.	0646	C SE 1/4, Sec. 13, T. 9 N., R. 5 E.; the samples of sandstone and shale were collected from a stream gully in the lower middle of the SE 1/4 about 1500 feet from the southeast corner of the section.

101.	2496	S 1/2 NW 1/4, Sec. 24, T. 9 N., R. 5 E.; sample collected from stream bed of Wewoka Creek as it crosses road in front of house.
102.	5719	NE 1/4 NW 1/4, Sec. 4, T. 9 N., R. 6 E.; a possible channel in the Vanoss, the sample was collected from a small bench associated with a gully trending northwest and about 150 feet south of county road.
103.	7165	SE 1/4 SW 1/4, Sec. 7, T. 9 N., R. 6 E.; collected of sand and shale these samples were taken at the intersection of Oklahoma Route 3 and a county road behind the homes in a shallow trench.
104.	8565	SW 1/4 SE 1/4, Sec. 8, T. 9 N., R. 6 E.; this sample was collected from the east bank of a stream about 200 feet north of the county road (east-west) and 1 mile east of Oklahoma Route 3.
105.	4141	SE 1/4 SE 1/4, Sec. 8, T. 10 N., R. 6 E.; located 250 feet south of barn and 200 feet west of house and about 450 feet north of Oklahoma Route 99A, it is about 1 mile west of Little, Oklahoma.
106.	1798	NW 1/4 NW 1/4, Sec. 9, T. 10 N., R. 6 E.; sample collected from broad southeastward trending ridge approximately 1100 feet southeast of section corner and midway between house and stream.
107.	0941	C N 1/2 NE 1/4, Sec. 20, T. 10 N., R. 6 E.; sample site is at the divide between two minor drainages 1 mile south and 1 mile west of Little, Oklahoma.

108.	3385	NW 1/4 NW 1/4, Sec. 28, T. 10 N., R. 6 E.; collected from the north slope of the stream less than 200 feet east of road and 0.3 mile south of corner of section, approximately 2 miles north of Varnum Church.
109.	6510	NW 1/4 NW 1/4, Sec. 33, T. 11 N., R. 6 E.; approximately 0.9 mile north of Interstate 40 overpass on east side of road at the flat top of the area above the bar ditch.
110.	4029	SW 1/4 SW 1/4, Sec. 33, T. 11 N., R. 6 E.; 400 yards south of Interstate 40 at top of bar ditch; trenched sample.



A.



B.

C.

D.

PLATE III

CLAY MINERAL TYPES OF THE VANOSS

A. Light colored cutan coating about subangular quartz, plagioclase, chert and opaque clasts. Cutan appears to be illite. Thin-section 6689, SE 1/4, Sec. 31, T. 4 N., R. 5 E.; crossed nicols, 35x.

B. Alteration of orthoclase crystal to kaolinite in "fresh" Troy granite; SW 1/4, Sec. 7, T. 2 S., R. 5 E.; thin-section 7057; crossed nicols, 35x.

C. Scanning electron photomicrograph of sample exhibiting ragged detrital kaolinite crystals; NW 1/4, Sec. 30, T. 1 N., R. 4 E., 5000x.

D. Scanning electron photomicrograph showing tiny crystals of kaolinite present on coarser kaolinite crystal; from NE 1/4, Sec. 6, T. 6 N., R. 6 E., 2500x.

PLATE IV

SELECTED PHOTOS OF HEAVY MINERALS FROM SANDSTONES AND SHALES

A. Sandstone sample showing two distinct grain sizes with rounded garnet, subhedral zircons, tourmaline and magnetite; SW 1/4, Sec. 12, T. 5 N., R. 5 E., mean grain size 4 ϕ, plane light, 100x.

B. Shale, laterally associated with above sample; note subhedral garnets, zircon, tourmaline and rounded zircon; mean grain size of sample 4.5 ϕ, plane light, 100x.

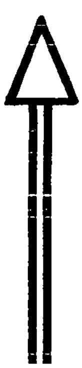
C. Typical association of rounded magnetite with subhedral zircon and rounded zircon in sandy shales of Vanoss; SE 1/4, Sec. 13, T. 5 N., R. 5 E.; mean grain size of sample 5 ϕ, plane light, 100x.

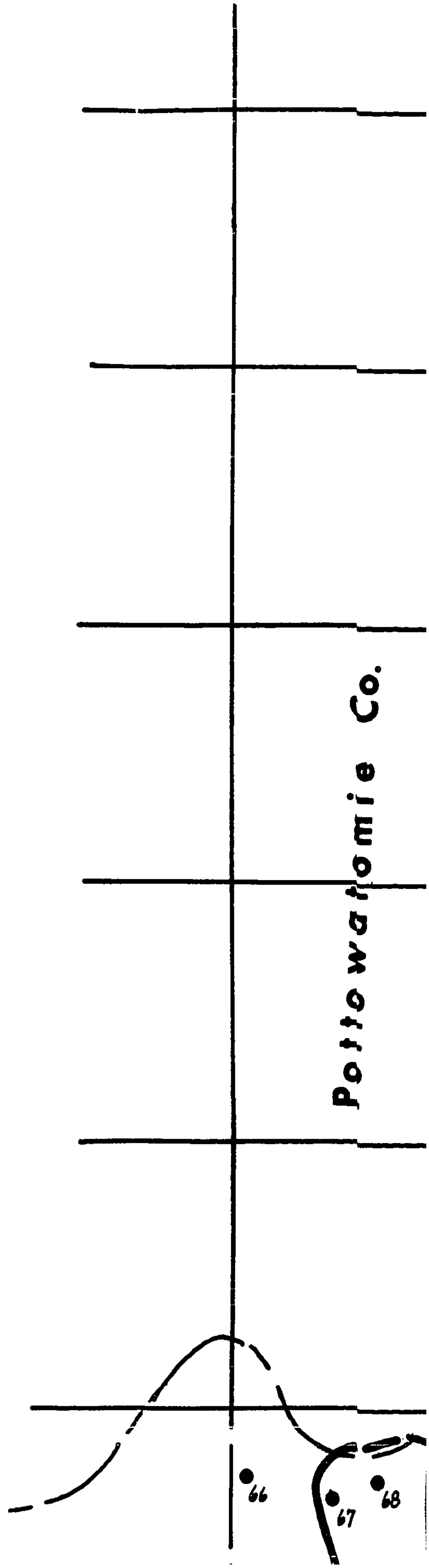
PLATE V

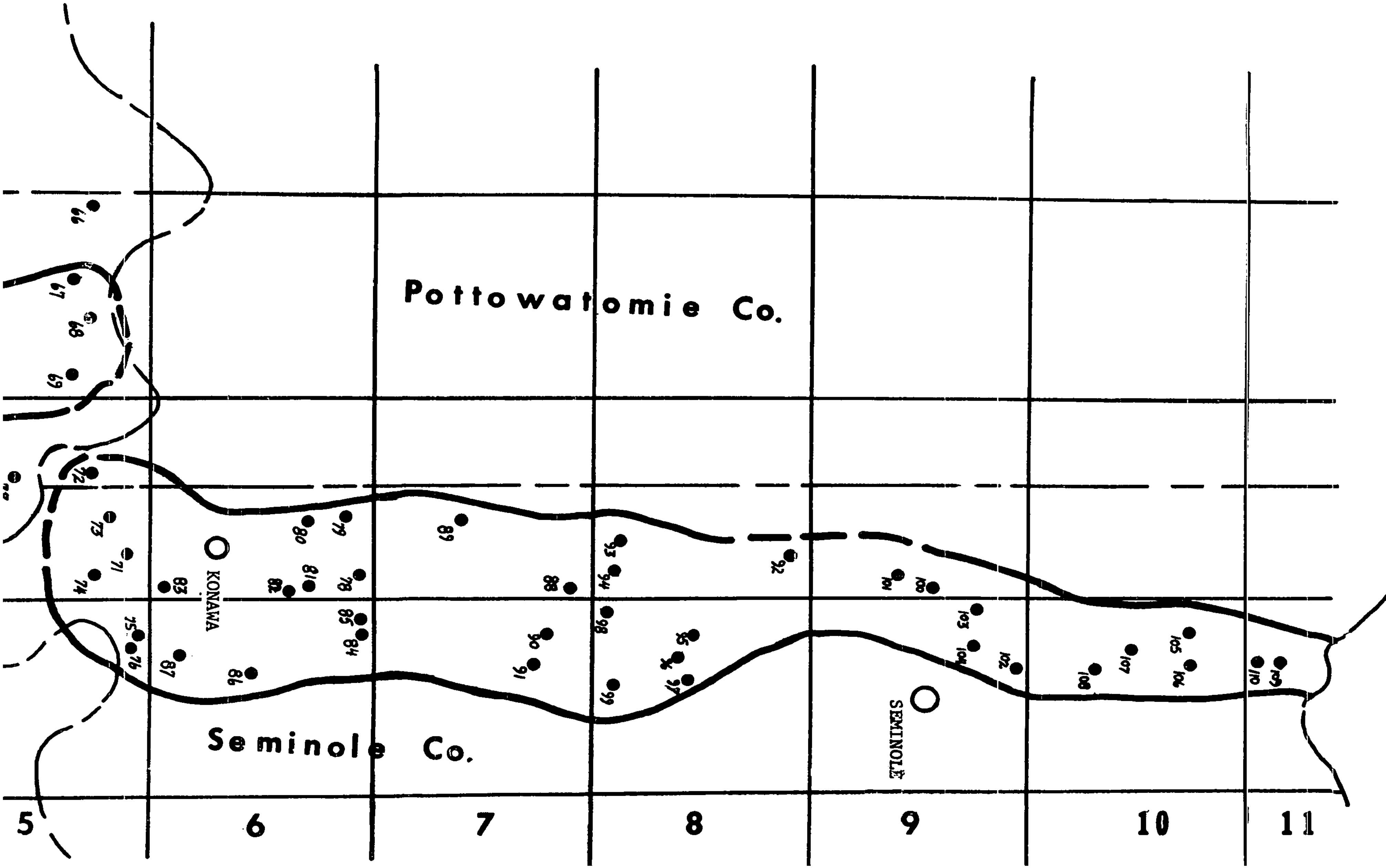
Sample Locations

●$_4$ = Thin-section sample site.
Numbers key locations to Appendix D.

N



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Seminole Co.
KONAWA
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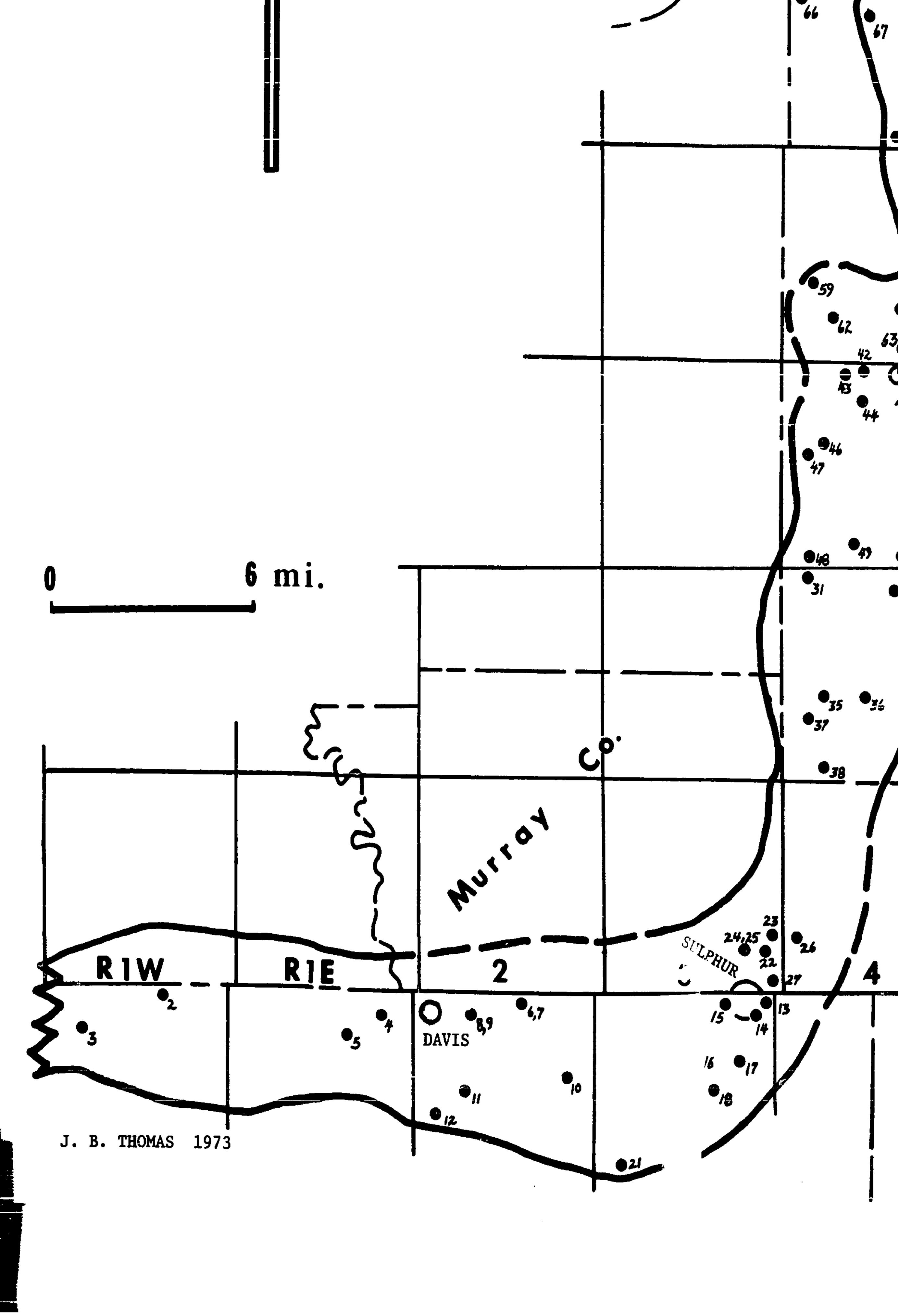
0 6 mi.
Murray Co.
R1W
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DAVIS
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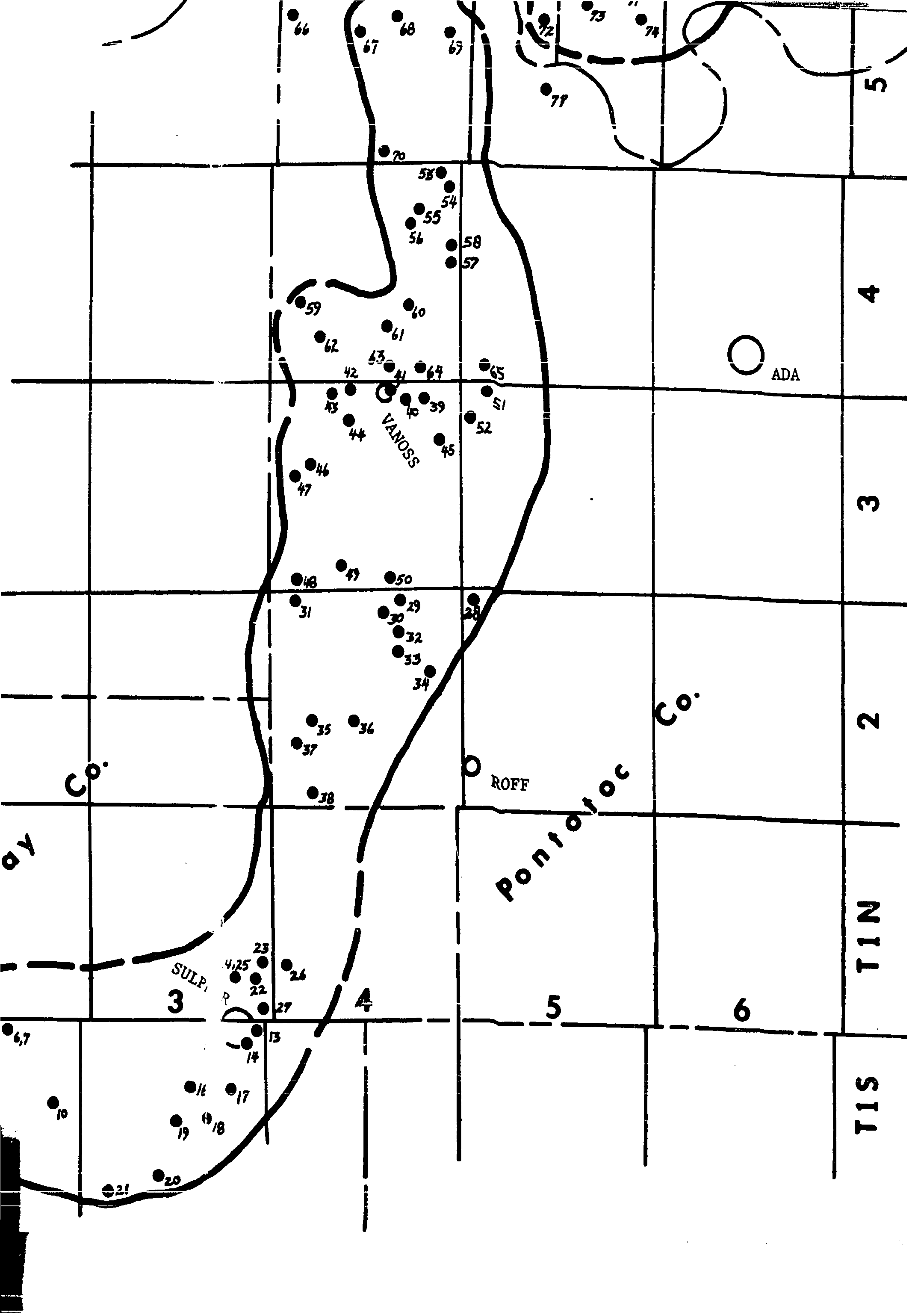
J. B. THOMAS 1973


ADA
VANOSS
ROFF
SULP
Pontotoc Co.
ay Co.
T1N
T1S
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4
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