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RANGE IN MAJOR CHEMICAL COMPONENTS OF CARBONATE ROCKS IN TENNESSEE

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ABSTRACT

The results of over 170 chemical analyses of carbonate rocks in Tennessee are presented on ternary diagrams. The samples were collected from widely separated places, and from various formations.

The distribution of the plotted points are interpreted as portraying the expectable range of composition for a formation. Thus, the diagrams are useful in predicting potential sources of limestone meeting chemical specifications.

The data indicate the Holston and Monteagle formations are the most probable sources of high-calcium stone, and the Honaker Dolomite the most likely source of high-magnesian stone in economic amounts.

INTRODUCTION

This paper presents by means of ternary diagrams the results of approximately 170 chemical analyses of carbonate rocks in Tennessee. The data are derived chiefly from an investigation of the limestones and dolomites by the Tennessee Division of Geology (Hershey and Maher, 1963), supplemented by analyses from the Tennessee Valley Authority files.

Crushed stone quarries operating in 1959 and 1960 were examined and sampled by the Tennessee Division of Geology during the investigation. The Geologic Branch of TVA has analyzed numerous carbonate rock samples from various localities in Tennessee for many years. The resulting data provide an accurate stratigraphic and geographic sampling of the principal carbonate formations in Tennessee; and the analyses portray the ranges of the chief chemical constituents in these rocks.

Contributions to this paper by W. D. Hardeman, Robert Hershey, and H. A. Tiedemann are gratefully acknowledged. Special thanks are due to B. C. Moneymaker, formerly Chief Geologist, TVA, for contributing data used herein.

METHODS

General

Carbonate rocks are at or immediately beneath the surface over approximately 50 percent of the area of Tennessee. As a consequence crushed stone is one of the largest items in the dollar list of Tennessee mineral production (over $62 million annually), and Tennessee ranks among the leading 10 states in tonnage of crushed limestone produced. The industry is widespread in the State; 63 of the 95 counties had at least one operating quarry in 1972.

The formations exploited for crushed limestone in Tennessee are all of Paleozoic age, chiefly Cambrian and Ordovician; however, rocks of Mississippian age also are an important source.

Tables 1 and 2 are condensed stratigraphic columns designed to emphasize the principal carbonate rock units in East and Central Tennessee, respectively.

TABLE 1: *Principal Carbonate Formations of East Tennessee.*

System	Group		Formation (Eastern)	Formation (Western)
ORDOVICIAN	Chickamauga Super Group	Stones River - Nashville	Tellico - Chapman Ridge	Leipers
				Catheys
			Holston	Cannon
				Hermitage
			Lenoir	Carters
				Lebanon
			Mosheim Member	Murfreesboro
				Pond Springs
	Knox Group	Upper	Mascot } Newala	
			Kingsport } Newala	
		Lower and Middle	Chepultepec	
			Copper Ridge	
CAMBRIAN	Conasauga Group		Maynardville } Honaker	
			Maryville } Honaker	
			Rutledge } Honaker	
			Shady	

TABLE 2: *Principal Carbonate Formations of Central Tennessee.*

System	Group	Formation
MISSISSIPPIAN		Pennington
		Bangor
		Monteagle
		St. Louis
		Warsaw
		Fort Payne
ORDOVICIAN	Nashville	Leipers
		Catheys
		Bigby-Cannon
		Hermitage
	Stones River	Carters
		Lebanon
		Ridley
		Murfreesboro

Crushed stone produced in Tennessee is used chiefly for concrete aggregate and roads (28.6 million tons), making cement and lime (2.5 million tons), and agricultural stone (2.5 million tons). Smaller tonnages go for metallurgical fluxing, coal mine dusting, glass, paper, filter beds, and riprap.

Demand for crushed stone has been increasing year by year, and it seems probable this growth will continue. Many consumers require stone meeting specifications that are based on chemical composition. The charts presented here should assist in identifying sources of stone meeting such specifications.

Use-suitability characteristics

Uses of carbonate rock may be subdivided generally into those that depend upon physical characteristics, and those that depend upon the chemical characteristics of the material involved. Physical properties are related to chemical composition of the rock, and in particular to the amounts of insoluble siliceous matter, and iron and aluminum oxides. Large amounts of silica, alumina, and iron oxides generally mean that the stone contains appreciable amounts of clay minerals or shale, and will abrade more rapidly than purer carbonates.

Relative amounts of calcium and magnesium carbonates in the rock have little to do with the value of the stone for general purpose and agricultural uses. However, chemical restrictions are stringent for uses that require high-calcium limestone, high-magnesian dolomite, and cement rock.

Major Chemical Constituents

The chemical analyses used in this compilation were reported as percentages of $CaCO_3$, $MgCO_3$, iron plus aluminum oxides, and SiO_2 as insoluble siliceous matter. In most instances the calcium and magnesium carbonates and insoluble siliceous matter constituted well over 95 percent of the rock. Ratios of these principal constituents were calculated assuming that the three major components summed to 100 percent, and were plotted in triangular diagrams overlain with a use-suitability chart (Figure 1). Industrial specifications used in preparation of the chart were discussed in some detail by Hershey and Maher (1963).

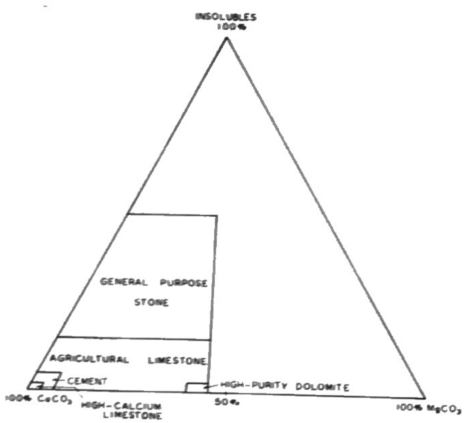

FIG. 1: *Use-suitability chart for carbonate rocks.*

DISCUSSION

East Tennessee Carbonate Formations

The Shady Dolomite (Figure 2) appears to be of fairly uniform character. Six analyses contain less than 60 percent $CaCO_3$ and 10 percent insoluble siliceous matter. Two of these analyses show more $MgCO_3$ than is possible in the theoretical composition of dolomite, and the rock may have contained other magnesium-bearing minerals. The formation is potentially suitable

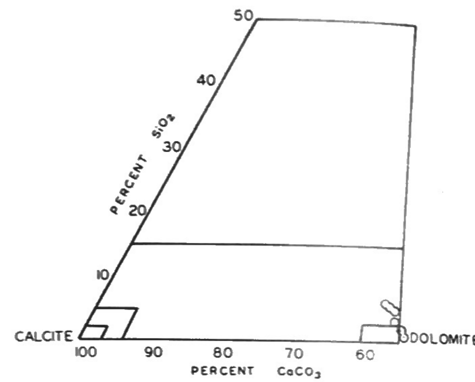

FIG. 2: *Composition of samples from the Shady Dolomite. Iron and aluminum oxides range between 0.32 and 1.52 percent.*

for general purpose stone, agricultural limestone; and in places where Fe_2O_3 is low, it may contain deposits of high-magnesian dolomite.

The Conasauga Group (Figure 3) is a heterogenous group consisting of shale, limestone, and dolomite formations. All but one of the carbonates tested is potentially suitable for agricultural limestone, and all would be suitable for general purpose stone. Deposits of high-magnesian dolomite are known from the Honaker Dolomite in northeastern Tennessee. (Rodgers, 1953). Analyses are available from two Honaker quarries, the Agricultural Lime Company, Inc., quarry, Greene County (active), and the Cranberry Furnace quarry, Carter County (long inactive). It should be noted that the assignment of the rock at Greeneville in Hershey and Maher (1963) to the Knox is an error. The quarry is developed in the Honaker.

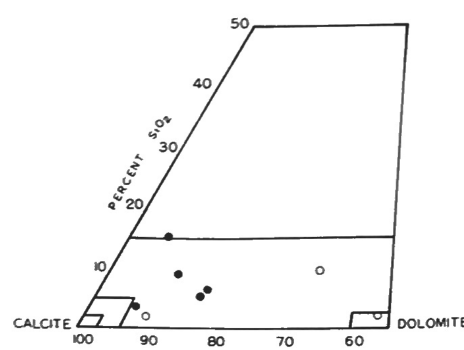

FIG. 3: *Composition of samples from the Conasauga Group. Solid circles represent the Maynardville Limestone. Iron and aluminum oxides range from 0.76 to 1.92 percent.*

The available Honaker analyses are shown in table 3.

The Knox Group is shown on two diagrams, lower and middle Knox, and upper Knox. Lower and middle Knox (Figure 4) includes the Copper Ridge and Chepultepec formations, and upper Knox (Figure 5) is Newala, or Kingsport and Mascot. Although the lower and middle Knox is more uniform in chemical composition than the upper Knox, both units are predominantly dolomite with a wide range of silica. The lower and middle Knox is potentially suitable for general purpose stone, agricultural stone, and in places for high-magnesian dolomite. The upper Knox has the same range of suitability. Three upper Knox analyses, obviously from limestone beds, show a chemical suitability for cement rock. It is unlikely, however, that stone suitable for cement manufacture would be found in mineable thicknesses within the Knox.

TABLE 3: *Analyses of Honaker Dolomite.*

Composition	1	2	3	4	5	6	7
$CaCO_3$	54.52%	55.50%	54.57%	54.95%	97.79%	97.79%	53.50%
$MgCO_3$	43.21	42.16	42.44	41.86	--	--	45.06
SiO_2	.70	.85	.65	1.30	1.26	1.40	.98
$Fe_2O_3+Al_2O_3$	.35	.60	1.00	.95	--	--	.37

1, 2, 3, 4 composites of 50-foot drill holes. Analyzed by Nichols Laboratory, Knoxville, 1965.

5, 6 Cranberry Furnace quarry, Milligan. Analyses by Company cited by Burchard (1913).

7, Cranberry Furnace quarry, analysis by James Eckman, U.S. Geological Survey, in Burchard (1913).

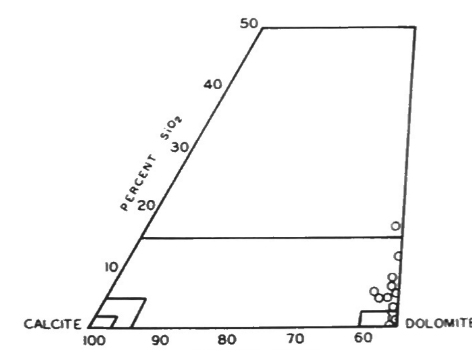

FIG. 4: *Composition of samples from the lower and middle parts of the Knox Group. Iron and aluminum oxides are generally less than 2.5 percent.*

The Chickamauga Group (excluding the Holston Formation) is a heterogenous group of formations; and contains shale, limestone and sandstone (Figure 6). Dolomite occurs in places but generally only in thin beds. Most of the Chickamauga limestones are poten-

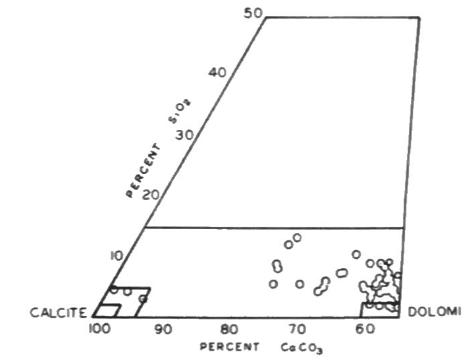

FIG. 5: *Composition of samples from the upper part of the Knox Group. Iron and aluminum oxides are less than 2.5 percent.*

tially suitable for general purpose stone, and some may be used for agricultural limestone or cement manufacture.

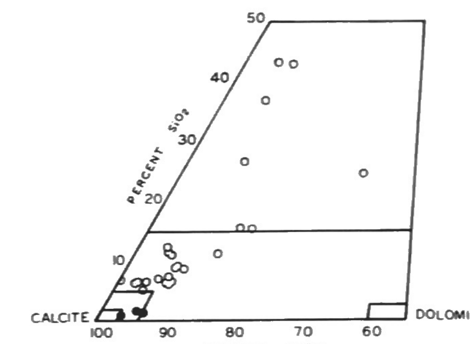

FIG. 6: *Composition of samples from the Chickamauga Group (exclusive of the Holston Formation). Solid circles represent the Mosheim Limestone. Iron and aluminum oxides range between 1.06 and 5.86 percent.*

The Holston Formation is the most homogeneous, and purest formation in Tennessee (Figure 7). Six of seven analyses plotted are within the small high-calcium limestone area, and the seventh is close by. The Holston therefore is potentially suitable for most uses, and has a high potential as a source for high-calcium limestone. However, phosphorus content should be considered for those uses in which it is deleterious.

The Pond Spring Formation (lower Stones River) is a dense, fine-grained limestone quarried in northern Georgia and the Chattanooga area. Analyses from sites in Georgia (Butts and Gildersleeve, 1948; see also Milici and Smith, 1969, for stratigraphic revisions) show it to contain 95 percent or more carbonates. It is satisfactory for agricultural stone and general purpose construction, but is marginal for cement owing to magnesium.

Central Tennessee Carbonate Formations

The principal carbonate formations of Central Tennessee are the Ordovician formations of the Central Basin of Tennessee, and the Mississippian formations of the eastern and western Highland Rims.

Ordovician formations are divided into the Middle Ordovician Stones River and Nashville Groups, and the Upper Ordovician Eden, Maysville, and Richmond Groups; their stratigraphy has been considered in detail by Wilson (1949). Analyses plotted herein are for three of the formations of the Stones River Group, the Ridley (3 analyses), Lebanon (3 analyses), and Carters (11 analyses) limestones (Figures 8 and 9), and for the formations of the Nashville Group combined. Upper Ordovician formations are generally more impure and shaly than underlying rocks; although they may be quarried locally for general purpose stone, they are not as important as the Middle Ordovician formations.

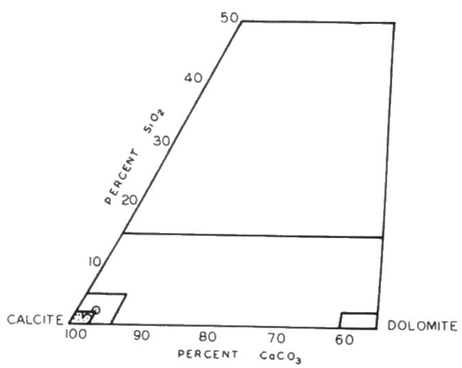

FIG. 7: *Composition of samples from the Holston Formation. Iron and aluminum oxides less than 2.0 percent.*

Stones River formations generally contain 90 percent or more $CaCO_3$, and 10 percent or less insoluble siliceous matter. All of the rock is potentially suitable for agricultural limestone, some for cement, and two analyses (one of the Carters and one of the Ridley) are within or close to the high-calcium limestone range.

The Nashville Group is composed of the Hermitage (3 analyses), Bigby-Cannon (7 analyses), and Catheys Limestone (2 analyses). Of the three formations the Bigby-Cannon is lowest in impurities (Figure 10); two analyses for the Catheys contain more insoluble siliceous matter or less $CaCO_3$ than the Bigby-Cannon; and three analyses of the Hermitage contain over 15 percent

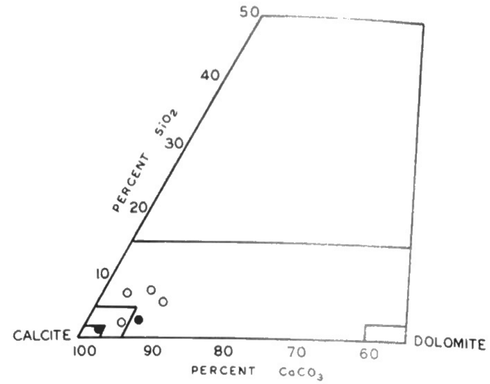

FIG. 8: *Composition of samples from the Ridley (solid circle) and Lebanon (open circle) Limestones. Iron and aluminum oxides range between 0.2 and 1.32 percent.*

insoluble siliceous matter. The Bigby-Cannon is suitable for general purpose stone and agricultural limestone. The less phosphatic Cannon and Dove facies are adapted to cement. Uses of the Catheys will probably be restricted to agricultural and general purpose stone.

The Mississippian carbonate formations of Central Tennessee are the Fort Payne, Warsaw, St. Louis, Monteagle (Ste. Genevieve-Gasper), and Bangor (Glen Dean) limestones. In general the Fort Payne Formation is much too siliceous to be of any use, although a few reef-like masses within the formation are composed of relatively pure limestone.

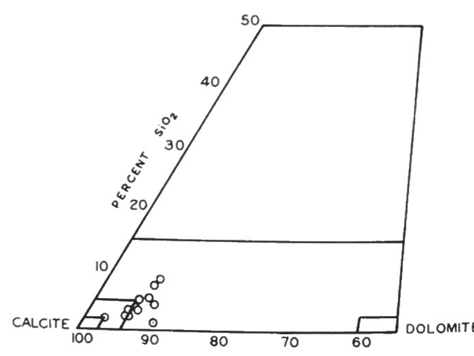

FIG. 9: *Composition of samples from the Carters Limestone. Iron and aluminum oxides range between 0.2 and 1.7 percent.*

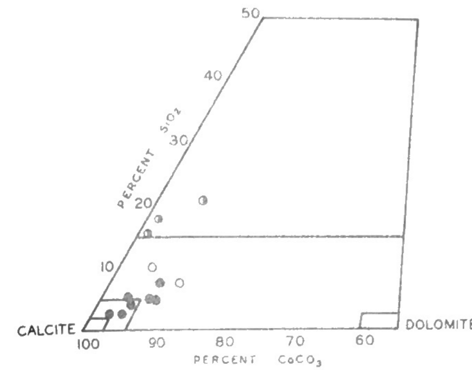

FIG. 10: *Composition of samples from the Nashville Group. Solid circles represent the Bigby-Cannon Limestone; open circles represent the Catheys Formation, and half circles the Hermitage Formation. Iron and aluminum oxides range between 0.52 and 4.01 percent.*

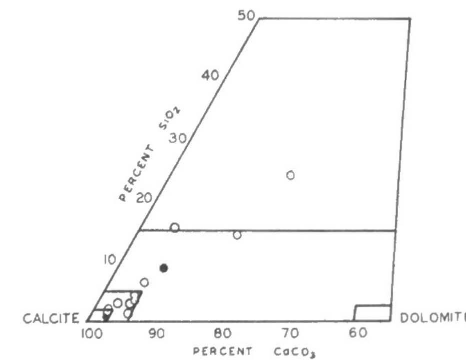

FIG. 11: *Composition of samples from the Warsaw, St. Louis and Bangor Limestones. Solid circles represent the Bangor. Iron and aluminum oxides ranbe between 0.2 and 4.5 peıcent.*

The Warsaw Formation (5 analyses, figure 11) has a considerable range of lithology, including limestone, arenaceous limestone, sandstone and shale. The rock is suitable for general purpose stone, agricultural limestone; in places the rock is suitable for cement; and one analysis plotted within the high-calcium limestone range. The St. Louis Limestone (6 analyses, Figure 11), is largely composed of limestone, siliceous limestone and dolomite. Available analyses plot within the general purpose stone, agricultural limestone, and cement rock use ranges. The Monteagle Limestone (16 analyses, figure 12) is the most homogeneous of the Mississippian formations. All but three of the analyses are within the cement rock range, and two are within the high-calcium limestone range. The three most impure samples analyzed are suitable for agricultural limestone manufacture.

The Bangor Limestone (2 analyses, figure 11) is suitable for general purpose stone, and for agricultural limestone. The formation probably is sufficiently pure in many areas for cement manufacture. An analysis reported by Hershey and Maher (1963, p. 148) of Monteagle (Ste. Genevieve-Gasper) and Bangor (Glen Dean) from the Penn-Dixie Cement Company in Marion County was probably from the Bangor; much if not all of the rock now quarried at this locality is Bangor and most is used for cement.

The lower Pennington Formation in places along the Cumberland Escarpment is sufficiently calcareous to be quarried for limestone. However, shale splits are common and the rock is not satisfactory for uses requiring over 85 percent carbonate content.

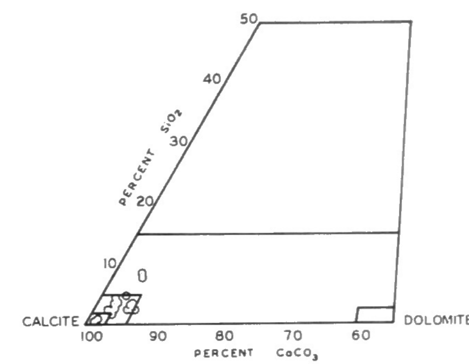

FIG. 12: *Composition of samples from the Monteagle Limestone. Iron and aluminum ranges betwene 0.14 and 1.20 percent.*

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