U. S. Geological Survey.

REPORTS-OPEN FILE SERIES, no. 1069: 1968.

U.S. Geological Survey

Reports-open file series, no. 1069; 1968.

Weld - Int. 2905

4

U. S. GEOLOGICAL SURVEY
Washington, D. C.
20242

[Reports - Open file series]

For release JULY 19, 1968

The U. S. Geological Survey is releasing in open file the following reports. Copies are available for consultation in the Geological Survey Library, 1033 GSA Bldg., Washington, D. C. 20242. Copies are also available for consultation in other offices as listed:

1. Preliminary geologic map of the Gold Hill quadrangle, North Carolina, by Harold W. Sundelius and Alfred R. Taylor. 1 map, scale 1:24,000. 11 Post Office Bldg., Knoxville, Tenn. 37902; Div. of Mineral Resources, Dept. of Conservation and Development, State Office Bldg. [P. O. Box 2719], Raleigh, N. C. 27602.

2. Redefinition of the terms Kingsport Formation and Mascot Dolomite as subdivisions of the upper part of the Knox Group in eastern Tennessee, by Leonard D. Harris. 53 p., 6 figs. 11 Post Office Bldg., Knoxville, Tenn. 37902; Dept. of Conservation, Div. of Geology, G-5 State Office Bldg., Nashville, Tenn. 37219.

3. Reconnaissance geology, mineral occurrences and geochemical anomalies of the Yentna district, Alaska, by A. L. Clark and C. C. Hawley. 86 p., including 7 figs. and 18 p. tabular data. Bldg. 25, Federal Center, Denver, Colo. 80225; 345 Middlefield Rd., Menlo Park, Calif. 94025; Brooks Bldg., College, Alaska 99701; 441 Federal Bldg., Juneau, Alaska 99801; 108 Skyline Bldg., 508 2nd Ave., Anchorage, Alaska 99501; 678 U. S. Court House Bldg., Spokane, Wash. 99201; 504 Custom House, San Francisco, Calif. 94111; 7638 Federal Bldg., Los Angeles, Calif. 90012; 1012 Federal Bldg., Denver, Colo. 80202; and in offices of the Alaska Div. of Mines and Minerals, 509 Goldstein Bldg., Juneau, Alaska 99801; 3001 Porcupine Dr., Anchorage, Alaska 99504; and University Ave., College, Alaska 99701. Material from which copy can be made at private expense is available in the Alaskan Geology Branch, USGS, 345 Middlefield Rd., Menlo Park, Calif. 94025.

4. Field descriptions of rocks from measured sections, Mt. Montro kyanite deposit, Grand Bassa County, Liberia, by Anthony Stanin and Bismarck Cooper. 13 p., 4 pl., 1 fig. Bldg. 25, Federal Center, Denver, Colo. 80225; 345 Middlefield Rd., Menlo Park, Calif. 94025.

5. List of references on the geology of Puerto Rico, 1866-1967, by Marjorie Hooker. 46 p.

6. Surficial geologic map of the Sugar House quadrangle, Salt Lake County, Utah, by Richard Van Horn. 3 sheets, scale 1:24,000. Bldg. 25, Federal Center, Denver, Colo. 80225; 1012 Federal Bldg., Denver, Colo. 80202; 345 Middlefield Rd., Menlo Park, Calif. 94025; 8102 Federal Office Bldg., Salt Lake City, Utah 84111. Material from which copy can be made at private expense is available in the Salt Lake City office.

7. Airborne electromagnetic and total intensity magnetic profiles in the vicinity of the Haile, Brewer, and Blackmon Mines, Lancaster, Chesterfield, and Kershaw Counties, South Carolina, by U. S. Geological Survey. 2 sheets, scale 1:125,000. Bldg. 25, Federal Center, Denver, Colo. 80225; 345 Middlefield Rd., Menlo Park, Calif. 94025; State Geologist, 1015 Main St., Room 216, Columbia, S.C. 29202. Material from which copy can be made at private expense is available in Columbia, S.C.

UNITED STATES DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Redefinition of the terms Kingsport Formation and Mascot Dolomite as subdivisions of the upper part of the Knox Group in East Tennessee

By

Leonard D. Harris

Open-file report

1968

68-119

CONTENTS

ILLUSTRATIONS

Redefinition of the terms Kingsport Formation and Mascot Dolomite as subdivisions of the upper part of the Knox Group in East Tennessee

---

By Leonard D. Harris

ABSTRACT

Upper part of the Knox Group has previously been divided into three formations; however, because of the lack of regionally recognizable boundaries, there has been a marked inconsistency as to the rocks assigned by different workers to the Longview Dolomite, Kingsport Formation and Mascot Dolomite. Regional stratigraphic studies have pointed out that there are only two recognizable major gross lithologic divisions. Because of this limitation, the term Longview, which has been used as a fossil zone, is abandoned; the term Kingsport is redefined to include the limestone and medium to coarsely crystalline dolomite unit, and Mascot is redefined to include the silty to very-finely crystalline dolomite unit from the top of the Kingsport to the unconformity at the top of the Knox Group.

The Kingsport Formation is divisible into three phases--a limestone phase, a collapse breccia phase, and a crystalline dolomite phase-- each of which intergrades on a basal and regional scale to seemingly form a consistent pattern. Many of the complexities of the Kingsport can be directly related to the development of the unconformity at the top of the Mascot Dolomite. Erosion associated with the unconformity produced a widespread karst topography with a subsurface drainage system. Ground water apparently reacting to difference in solubility between limestone of the Kingsport and dense dolomite of the Mascot is thought to be a major contributing factor in the regional localization of solution-thinning and collapse features at the contact of the redefined Kingsport and Mascot. Because of the extensive regional development of solution features, the true original thickness of the Kingsport is difficult to ascertain. The Mascot tends to thicken by dilatation as it collapses into void space created by solution in the Kingsport. However, regionally overall thickness of the Mascot decreases in response to beveling by erosion during development of the unconformity at the top of the formation.

Chert is found to be a major element in both the Kingsport Formation and the Mascot Dolomite, and its abundance is directly related to sedimentary and later processes. Primary chert in the form of lens and nodules is not abundant; however, penecontemporaneous chert that has replaced primary structures before dolomitization and secondary cherts, that commonly occur in and near breccia bodies or as matrix material in medium to coarsely crystalline dolomite, are abundant. Algal stromatolites, commonly replaced by chert, are important rock builders, forming as much as 35 percent of the Kingsport and about 25 percent of the Mascot.

INTRODUCTION

Subdivision of the upper part of the Knox Group in east Tennessee into stratigraphic units received its greatest impetus from the fact that commercial zinc deposits were found to be confined to definite rather thin stratigraphic zones in the upper part of the Group. Thus, an understanding of the detailed stratigraphy was essential for preparation of geologic maps and the exploration and extraction of ores. The presently accepted nomenclature, for the upper part of the Knox Group northwest of the Pulaski thrust fault (fig. 1), was largely developed in the Mascot-Jefferson City zinc district through the efforts of Bridge and Oder (Rodgers, 1953, p. 54). In the late thirties these men apparently agreed to use the terms Longview Dolomite, Kingsport Formation, and Mascot Dolomite as major subdivisions of the upper Knox.

Although Bridge and Oder agreed to use of the terms Longview Dolomite, Kingsport Formation, and Mascot Dolomite as subdivisions of the upper Knox Group, they apparently never firmly agreed to the precise stratigraphic intervals to be included in the Longview and Kingsport (Bridge, 1956, p. 46-51). This lack of agreement can be traced to the fact that each man had different objectives for developing subdivisions of the Knox. Oder, as Chief Geologist of American Zinc Company had through mine workings and numerous core holes unlimited access to local detailed stratigraphic information in the Mascot-Jefferson City zinc district. However, because of the economics of mining, Oder had no particular need for gross stratigraphic units, rather he had to stress the concept of key bed stratigraphy for use as guides in exploration and mine development. For many years the American Zinc Company geologists had been developing a detailed system of nomenclature based on certain thin key stratigraphic units that could be recognized in their mines, but these detail studies were limited to the Kingsport and Mascot. Bridge and Oder apparently agreed to use one of these key units--the chert matrix sandstone of Oder--as the stratigraphic boundary between the Kingsport and Mascot, but the contrast between the Longview and Kingsport was not clearly resolved (Bridge, 1956, p. 50). Utilizing this partial agreement with Oder, Bridge developed his concept of the Longview, Kingsport and Mascot and mapped these units in the Mascot-Jefferson City zinc district. Because of poor exposures, Bridge had limited access to detailed stratigraphic information, he therefore had to develop a series of mapping criteria based on the insolubles contained in the residuum. He did this by attempting to relate residual products to a very few exposures. As thus conceived, his mapping units were based partly on lithology and mainly on his ability to interpret residual accumulation of specific kinds of chert, occurrence of fossils or other readily identifiable residual products. How well he did this is attested to by the fact that drilling by zinc companies has proven the reliability of his map (Bridge, 1956, p. 5).

Though not the intent, a major result of the partial collaboration of Bridge and Oder has been the firm establishment of two separate approaches to the extension and generation of basic data concerning subdivision of the upper part of the Knox Group. One approach, employed by the zinc companies, is based on detailed stratigraphy of a limited part of the section, and the other approach, used by surface mappers, is the extension of map units based on interpretation of residual products with little or no attention given to bedrock. Of the two methods, the zinc companies under the leadership of Oder (Oder and Miller, 1945; Oder and Ricketts, 1961), Crawford (1945), Hoagland, Hill, and Fulweiler (1965) have by far contributed the most to the understanding of the basic details of the stratigraphy. Surface workers have not been as consistent. Early disciples of Bridge were able to make a beginning at the extension of his units. However, since the publication in 1956 of Bridge's description of the formations, little progress has been made. This has been brought about by the difficulty of recognizing regionally thin key units in residuum and other identifiable entities used by Bridge. About 70 percent of the quadrangle maps published in east Tennessee since 1956 have not used the terms Longview, Kingsport, and Mascot as separate map units, instead a whole series of terms have been devised to enable the various authors to map units they thought could be recognized. The most commonly used mapping units are the Longview and Newala Dolomite, the Newala is thought to include the Kingsport and Mascot undivided. Other commonly used map units include the Chepultepec, Longview, and Kingsport undivided, the Chepultepec, Longview, Newala undivided and the upper Knox Group undivided.

This report attempts to reconcile the two points of view presently used in extending knowledge of the Knox Group so that map units may coincide with rock units, thus becoming meaningful regional subdivisions. Contained in this report is a revision of nomenclature and a regional stratigraphic analysis of the upper part of the Knox Group, based on data from intense exploration and mining by zinc companies and from a series of surface sections measured along strike on the several fault belts of east Tennessee and parts of southwest Virginia.

DEVELOPMENT AND INCONSISTENCY IN USE OF THE TERMS LONGVIEW DOLOMITE, KINGSPORT FORMATION AND MASCOT DOLOMITE

Earliest workers in east Tennessee treated the rocks of the present Knox Group as a single lithologic unit (Safford, 1869; Campbell, 1894; Hayes, 1894; Keith, 1895). As more regional information accumulated throughout the Valley and Ridge Province of eastern United States, Ulrich (Gordon, 1924; Secrist, 1924) proposed several subdivisions; however, it was 1934 before the first detailed description of stratigraphic units in Knox was published. At that time Hall and Amick (1934) presented their now classic Thorn Hill section, which includes detail description of rocks from Middle Cambrian to Middle Ordovician. Because of excellent exposures and the fact that Hall and Amick painted their unit numbers on the rock so that individual units could be retrieved, the Thorn Hill section has become one of the standard reference sections for the Knox of east Tennessee. In the same year Oder (1934) published his preliminary subdivision of Knox and included description of several sections including Thorn Hill, but not in the detail of Hall and Amick. Subdivision of the Knox as used by Hall and Amick differed substantially from that used by Oder (fig. 2); however, neither received much support from the geologic community.

Bridge (1956) summarizes in much more detail than this report the early history of the nomenclature of the Knox Group and points out that many of the earlier terms used in Tennessee were not suitable because: (1) some formations were confused with faunal zones with the result that failure to recognize the fossils resulted in not recognizing the limits of the formation, and (2) the definition of formations in their type areas, some of which were in States many miles removed from Tennessee, was not clearly understood and no two workers agreed to the same stratigraphic limits. In their desire to establish a satisfactory subdivision of Knox, Bridge and Oder collaborated in the thirties to develop the nomenclature presently used for the Knox Group. These subdivisions from oldest to youngest include the Copper Ridge Dolomite, Chepultepec Dolomite, Longview Dolomite, Kingsport Formation, and the Mascot Dolomite. This report concerns itself only with the Longview, Kingsport and Mascot subdivisions.

Despite the fact that in the early 1940's neither Bridge nor Oder had published descriptions of their subdivisions of the Knox Group, their nomenclature was pressed into use during World War II in the strategic minerals program. This was largely due to fact that the Bridge technique of mapping residuum had proven successful in a local area and there was a definite need to extend subdivision of the Knox into favorable mineralized areas. Subsequently, all or parts of the Bridge-Oder classification was used by many authors (Rodgers, 1943; Bridge, 1945; Oder and Miller, 1945; Crawford, 1945; Dunlap and Rodgers, 1945; Brokaw and Jones, 1946; Rodgers and Kent, 1948; Miller and Fuller, 1954; and Miller and Brosge, 1954). This, of course, firmly established the terms Longview, Kingsport, and Mascot in the literature.

The first basic insight into the significance of the details of stratigraphy of a portion of the upper part of the Knox Group was published in separate papers by Crawford (1945) and Oder and Miller (1945). These papers, even though they presented somewhat different points of view in the method of subdivision, did for the first time point out that there are many key stratigraphic units that could be used in the Mascot-Jefferson City district for correlation.

Crawford (1945) emphasized that the fact that rocks in and immediately above the commercial zinc producing part of the upper part of the Knox Group could be subdivided into a series of lithologic units from 4 to 60 feet thick to which he assigned the letters "M" through "V" (fig. 4, U. S. Steel key units). He indicated that the ore occurred in the Kingsport Formation (p. 408) but did not make clear as to which of his lettered units he assigned to the Kingsport.

In describing the same ore producing zone Oder and Miller (1945) emphasized the key bed approach--a system devised for the American Zinc Company by M. H. Newman and H. F. Mills (Oder and Mller, 1945, p. 9). In this system separate foot by foot detail sections were compiled from subsurface data in each of the American Zinc Company's three mines in Mascot, New Market and the Jefferson City area. "Individual layers often were treated as distinct units. The bed that first was considered the foot wall of the known ore in each mine was assumed as a datum or zero bed. Each unit above or below that bed was given a number corresponding to the actual measured interval between the datum and the unit being described. For example: an important black dolomite, 28 feet above the zero bed at New Market, is called the '28 bed'"(Oder and Miller, 1945, p. 4)." In essence the American Zinc Company by treating each mine as a separate entity, set up a tripartite numbering system, which is necessary for mine development but does tend to complicate the comprehension of the stratigraphy by having three different numbers for the same key unit. (fig 4).

Although Oder and Miller (1945) used the terms Longview Dolomite, Kingsport Formation, and Mascot Dolomite as major subdivisions of the upper part of the Knox Group, they made no attempt to define the limits of the formations. Instead, they concentrated on a detailed description of the Kingsport without mentioning its basal contact. They ignored the major facies change from limestone to silty or very finely crystalline dolomite at the 82-28-115 bed, or the top of R bed of Crawford, and chose instead, a 6-inch sandstone (chert-matrix sandstone of Oder) from 184 to 212 feet above the 82-28-115 bed as the contact between the Kingsport and Mascot (fig. 3, sections 0, 1 and 2). Apparently this contact was arbitrarily chosen because key units as small as a fraction of an inch could be correlated above the 82-28-115 bed, but units below that bed could not be correlated with confidence (Oder and Miller, 1945, p. 8). This lack of correlating tools beneath the 82-28-115 bed probably contributed to the fact that they did not select a basal contact for the Kingsport. However, Allen (1947) an associate of Oder suggested that the basal contact of Kingsport should be extended to include the Longview. Later, Oder and Ricketts (1961, pl. 2) tentatively placed the basal contact of the Kingsport at the -88 bed of the New Market mine and moved the upper contact down about 45 feet to the 192 bed, which is apparently a more persistent chert-matrix sandstone (fig. 3, section 1).

Presently the two different systems of detailed stratigraphy discussed by Crawford (1945) and Oder and Miller (1945) with some modification are used by the different zinc companies in east Tennessee (fig. 4). The American Zinc Company and Tri-State Zinc Company use the Oder system, U. S. Steel uses the Crawford system, and The New Jersey Zinc Company uses a combination of the Crawford-Oder system at their Jefferson City mine and a combination of the Crawford system plus local key beds at their Flat Gap mine in the Copper Ridge district.

The first detailed stratigraphic description of the Longview Dolomite, Kingsport Formation and Mascot Dolomite was published by Rodgers and Kent (1948). These men, like Hall and Amick (1934), measured a well exposed section of rocks from Lower Cambrian to Middle Ordovician at Lee Valley, Hawkins County, Tennessee. In discussing the Longview Dolomite, Rodgers and Kent make it quite clear that their definition of the Longview is not lithologic, but is a faunal zone. The basal contact at Lee Valley is drawn arbitrarily at a minor change in lithology and the upper contact with the Kingsport is placed at the highest occurrence of the gastropod Lecanospira (Rodgers and Kent, 1948, p. 22). The Kingsport was described as consisting "typically of thick-bedded compact blue to brown limestone below, interbedded with and grading into light to dark gray finely crystalline well bedded dolomite" (Rodgers and Kent, 1948, p. 25). The upper contact with the Mascot was taken at the first occurrence of three or four chert-matrix sandstones which was thought to correspond with the chert-matrix sandstone of Oder (Oder and Miller, 1945, p. 5-6). The Mascot was described as "light gray finely crystalline to compact well bedded dolomite" with its top being marked by an unconformity (Rodgers and Kent, 1948, p. 28-32).

Bridge (1956, p. 46-56) reinforced the Rodgers and Kent (1948) definition of the Longview Dolomite, Kingsport Formation and Mascot Dolomite by citing their numbered units as correlatives of the contacts he would use. However, Bridge made one major addition; he published his measured section of the Kingsport at its type locality of Kingsport, Tennessee.

A comparison of the Bridge type section of the Kingsport Formation with the Lee Valley, Thorn Hill, and Mascot-Jefferson City sections points up the fact that there is an almost complete lack of agreement as to what stratigraphic intervals constitute the Longview, Kingsport and Mascot Formations (fig. 3). A generalized section compiled from figure 3 showing in one section all contacts as used by the several authors, demonstrates that there are at least six different "chert-matrix sandstones" in a 125 foot interval that have been used as the contact between the Kingsport and Mascot; four different contacts for the Longview and Kingsport and three different contacts for the Chepultepec and Longview. It seems obvious that if people who are well acquainted with details of the upper part of the Knox Group cannot agree upon the stratigraphic limits of the Longview, Kingsport and Mascot, then it is unreasonable to assume that geologists who are less well acquainted can effectively use these subdivisions as map units or in regional stratigraphic studies. This in fact is the case for in about 70 percent of the maps published since 1956 geologists have not attempted to map the Bridge-Oder three-fold subdivisions, rather they have chosen instead to be less specific and have mapped all three units undivided or have used two map units. Whether or not the map units as used by the latest workers are consistent within a given area or whether they encompass the same general stratigraphic intervals as used by Oder or by Bridge is purely conjectural.

REDEFINITION OF THE TERMS KINGSPORT FORMATION AND MASCOT DOLOMITE

If one disregards the multitude of contacts in figure 3 and instead looks at the gross lithologic sequence, it is readily apparent that the sequence is divisible into a limestone and medium to coarsely crystalline dolomite unit, which is overlain and underlain by silty to very finely crystalline dolomite. Stratigraphic studies have shown that this limestone-crystalline dolomite unit is regionally persistent (fig. 5). Heretofore, this unit has not been considered a single lithologic sequence, rather it has been about equally divided between the Kingsport Formation and the Longview Dolomite. Accordingly the writer proposes to (1) abandon the term Longview, because as it has been used, it is a fossil zone and not as a lithologic unit, (2) to redefine the Kingsport Formation to include the limestone and crystalline dolomite sequence and (3) to enlarge the Mascot Dolomite to include all beds above the redefined Kingsport up to the unconformity at the top of the Knox Group.

Kingsport Formation

The redefined Kingsport Formation includes beds 417 to 480 in the Thorn Hill section (Hall and Amick, 1934, p. 204-206), the upper three feet of unit 204 to unit 243 in the Lee Valley section (Rodgers and Kent, 1948, p. 23-26), and key beds -133 to 82 of the Mascot section (Allen, 1947, fig. 4). Even though it is possible to carefully document the limits of the redefined Kingsport Formation in relation to previously published detailed sections, these sections do not fully describe the Kingsport, rather they describe but one phase of the formation. This is true because published detailed sections in Tennessee, including those of Oder and Miller, 1945, and Bridge, 1956, all tend to stress the limestone content of the Kingsport, when, in fact, the Kingsport has a wide range in rock types both on a local and regional level. In general the Kingsport is composed of two dominant rock types, limestone and medium- to coarsely crystalline dolomite with a few interbeds of silty to very-finely crystalline dolomite. The proportion of limestone to dolomite varies both on a local and regional scale; however, there is a general facies change toward the north and northeast from limestone and medium to coarsely crystalline dolomite to dominantly medium to coarsely crystalline dolomite (fig. 5). Superimposed upon this facies change are certain other fundamental changes within the sequence that tend to mask its identity. It is not unusual for limestone in the upper half of the redefined Kingsport to be partially or wholly replaced on a local level by breccia zones or to be completely dolomitized. Enough detailed work has been done to suggest that the breccia zones are the result of geologic processes operating subsequent to the deposition of the Kingsport. In order to focus attention on the complexities of the redefined Kingsport, its description in this report is divided into three parts--a limestone phase, a collapse breccia phase, and a crystalline dolomite phase. It must be emphasized that even though each phase is distinct, lithologies characteristic of each actually intergrade on a local and regional level to seemingly form a pattern.

Limestone phase

Limestone forms a high percentage of the total rocks assigned to the redefined Kingsport Formation in the Mascot-Jefferson City zinc district (fig. 3) and in sections 6, 9, 13, and 26 in figure 5. Typically these sections each contain about 50% limestone with the rest of the formation composed of medium to coarsely crystalline dolomite with an occasional bed or thin zone of silty to very-finely crystalline dolomite. The most regionally persistent limestone units occur in the upper part of the Kingsport and have been referred to as the S and R beds by Crawford (1945).

Limestone in the Kingsport Formation is light olive gray in even beds from one inch up to two feet thick, that are commonly marked by abundant styolites. Texture is predominantly lutite, but there are occasional thin beds of intraformational conglomerate, fine pellet or oolitic limestone. The most prominent feature of the limestone phase is the abrupt change from section to section or even in a hand specimen of limestone to medium or coarsely crystalline medium gray dolomite. It is not uncommon to be able to trace in a single outcrop the transition of limestone to crystalline dolomite and back to limestone. Even though the contact between massive dolomite and limestone is usually sharp, minor dolomitization can be seen to extend outward a few inches or feet into limestone units along styolites or as small randomly spaced irregular crystalline areas. Medium to coarsely crystalline dolomite seems to be clearly a replacement phenomenon for primary structures such as minor partings and styolites as well as accessory elements such as thin sandstone beds or chert nodules can be traced from the limestone into the crystalline dolomite.

Silty to very-finely crystalline light gray dolomite forms a minor part of the total Kingsport Formation; however, this particular type of dolomite is the most persistent regional element. Its persistence suggests that it was an early sedimentary feature not appreciably altered by later events. Generally the silty to very-fine crystalline dolomite is restricted to units from 1 to 15 feet thick. Individual beds or zones may be distinctive because they are uniformly structureless or may contain primary structures, such as faint wavy laminae, or strong even lamination or mottling. Chert nodules and/or quartz sand as floating grains or as thin beds are common accessory elements.

Chert is a conspicuous element throughout the Kingsport Formation; however, its occurrence and abundance seems to be related to both the early deposition environment and to much later events. Cherts discussed under the limestone phase are those thought to be primary or penecontemporaneous with deposition of limestone. Other types of chert that seem to accompany alteration of limestone to crystalline dolomite will be discussed under the collapse breccias and crystalline dolomite phases.

Chert is moderate to locally abundant in the limestone phase of the Kingsport Formation. It may occur as nodules from an inch up to several feet long or in beds from one inch up to more than 1 foot thick. Individual chert beds seem to be of two general types (1) those that are essentially structureless, containing a few dolomolds or only faint bands and (2) beds that clearly have replaced primary structures in limestone before dolomitization has occurred. Chert nodules and the essentially structureless chert beds quantitatively make up less than 20 percent of the total chert in any limestone section. Structures that are common in the penecontemporaneous chert are oolites, intraformational conglomerate and algal stromatolites. Neither oolites or intraformational chert types are abundant; however, oolitic chert beds do occur in persistent zones near the base and upper half of the Kingsport.

By far the most conspicuous element of the penecontemporaneous cherts is algal stromatolites. Algal stromatolites are laminated structures that owe their origin to the activity of an algal mat. Recently, Logan, Rezak, and Ginsburg (1964) proposed to abandon all generic and specific names of algal stromatolites and substitute a geometric classification. Stromatolites in the Kingsport Formation seem to be restricted to the Logan and others type SH-C, which is described as a discrete hemispheroidal structure composed of vertically stacked lamina that reach or overlap preceeding laminations without an increase in basal radius (Logan, Rezak, and Ginsburg, 1964, p. 74-75). Rarely in the Kingsport are all parts of the SH-C stromatolites preserved, normally the upper half has not been silicified. When weathering has released the SH-C into the residuum, one usually sees a donut shape laminated chert body or a circular laminated chert mass that resembles an onion cut in half to show the concentric growth laminae. In carefully studied sections algal stromatolites have been found to make up as much as 35 percent of the total Kingsport and the vast majority of the bodies have been replaced by chert (fig. 5, sec. 26).

In the limestone phase and crystalline dolomite phase both the upper contact of the Kingsport Formation with the Mascot Dolomite and the lower contact with the Chepultepec Dolomite are distinct. Each is marked by an abrupt change from the limestone or medium to coarsely crystalline dolomite typical of the Kingsport to a thick sequence of silt to very-finely crystalline very light gray dolomite that contains only minor amounts of fine to medium crystalline dolomite (fig. 5).

Collapse breccia phase

It is not uncommon for the redefined Kingsport Formation to be mainly limestone in one section and in an adjacent section to be completely dolomitized or to have part of its position occupied by a large breccia zone. The breccia bodies range in width from 30 feet up to several hundred feet and extend for hundreds of feet in length (Oder and Ricketts, 1961, p. 8-9; Kendall, 1960, p. 993). Kendall (1960, p. 998) in describing breccia bodies in the U bed indicated that their margins are marked by an abrupt change from dolomitized limestone to limestone--thus they resemble steep walled channels filled with dolomite debris. Because zinc mineralization is usually found near the contact between breccia and limestone, mining removes all breccia and leaves the barren limestone wall. A mine map of the U bed shows that in plan view the breccia bodies form an interconnected reticulate system (Kendall, 1960, p. 991, fig. 4), resembling present day solution patterns in limestone terrane.

In the past it was thought that major breccia zones had a tectonic origin and probably resulted from the Appalachian orogeny (Keith, 1896, p. 5; Purdue, 1912, p. 27-28; Secrist, 1924, p. 160; Newman, 1933, p. 159; Currier, 1935, p. 272; Laurence, 1939, p. 192; Crawford, 1945, p. 441; Bridge, 1956, p. 71; Oder, 1958, p. 53). Other authors have described all or parts of these breccia zones as collapse features associated with cave development (Ulrich, 1931, p. 31), as founder breccias associated with hydrothermal solution (Odell in Oder and Hook, 1950, p. 78, and Ridge, 1968, p. B10-11), as conglomerates associated with weathering of the Longview shortly after its deposition (Miller and Brosgé, 1954, p. 26-27; Oder and Ricketts, 1961, p. 6-7) or as sedimentary structures related to deposition (Kendall, 1960, p. 998). Recognition by Kendall (1960, p. 993-995; 1961, p. 1137-1138) in the breccia bodies of matrix material containing laminations parallel to the strike and dip of country rock, led him to conclude that the breccia zones antidate the Appalachian orogeny and developed when the Knox was flat lying. This significant contribution has given impetus to a re-examination of the genesis of the breccia bodies. Currently many geologists in the district support the idea that these breccia bodies are solution-collapse features related to the unconformity at the top of the Knox (Oder and Ricketts, 1961, p. 16-18; Wedow and Marie, 1964, p. 262; Callahan, 1964, p. 224-227; Wedow and Marie, 1965, p. B22; Hoagland, Hill and Fulweiler, 1965, p. 699-700). This concept is based on the well documented fact (Butts, 1940, p. 119; Cooper and Prouty, 1943, p. 823-824; Laurence, 1944; Rodgers and Kent, 1948, p. 32; Miller and Fuller, 1954, p. 67; Miller and Brosgé, 1954, p. 30-32; Bridge, 1955, Bridge, 1956, p. 57-59; Harris, 1960) that the Knox was exposed to extensive erosion shortly after its deposition. Some idea of the irregularities as well as the amount of relief developed on this surface can be seen in figure 5, where total relief is on the order of 350 feet. In addition that figure illustrates that many lows on the unconformity surface directly overlie collapse breccia bodies in the Kingsport, suggesting that localization of at least some collapse features are directly related to the unconformity. Hoagland, Hill, and Fulweiler (1965, p. 700-702) describe local occurrence in breccia bodies of grayish-red dolomitic shale and attribute its origin to leak from the unconformity. This type of grayish-red shale can be found to fill dilatation fractures and to occur in breccia bodies from the unconformity at the top of the Mascot to beds in the upper part of the Chepultepec Dolomite (fig. 5, secs. 14, 16 and 20).

Erosion accompanying the development of the unconformity at the top of the Mascot produced a widespread karst topography with an attendant subsurface drainage system. Ground water apparently reacting to differences in solubility is thought to be a major factor in the regional localization of solution at the contact of the redefined Kingsport and Mascot (Wedow and Marie, 1964, p. 262). Both Wedow and Marie (1965, p. B22) and Hoagland, Hill and Fulweiler (1965, p. 706) stress the importance of the lithologic change from limestone of the redefined Kingsport to dolomite of the redefined Mascot by pointing out that collapse structures were initiated by solution thinning and dolomitization of limestone of the Kingsport. In extreme cases about the upper 100 feet of limestone of the redefined Kingsport is reduced to 20 feet of breccia (Hoagland, Hill, and Fulweiler, 1965, p. 706). Oder and Ricketts (1961, p. 16) in discussing the same general interval cite a reduction of 160 feet limestone to 60 feet of altered material. Measured sections in figure 5 tend to confirm their observation for no major collapse bodies were found not associated with the redefined Kingsport and Mascot contact.

Because the role of solution thinning and collapse in the Kingsport Formation has only recently begun to be fully appreciated and studied, little has been written to clarify the concept. Information that is available is fragmentary or incomplete. Nevertheless, enough data when placed in the proper perspective, are available to present a reasonable synthesis of the concept.

In order to illustrate the concept of solution-thinning and collapse, Hoagland, Hill, and Fulweiler (1965, p. 698, fig. 2) present a series of sections that show changes occurring between what they called an unmineralized section and an intensely mineralized section. They confine their discussion of solution and collapse features to about the upper half of the redefined Kingsport Formation and the lowermost beds of the redefined Mascot Dolomite. However, regional stratigraphic studies (fig. 5) suggest that solution and collapse is not completely confined to the particular part of the Kingsport discussed by those authors; instead, it may occur throughout the redefined Kingsport. Figure 6A which is based on the Hoagland, Hill and Fulweiler illustration, clearly shows that as limestone of the upper part of Kingsport Formation is reduced in thickness by solution and/or dolomitization, void space thus created id distributed upward by dilation to form cracked to rubble breccia. Wedow and Marie (1965, B22) suggest that as the Kingsport is thinned by solution, the less soluble Mascot Dolomite tends to thicken by sag and dilatation. This particular facet of the solution-thinning and collapse concept is not well shown in the Hoagland, Hill, and Fulweiler sections; however, that phenomenon is well illustrated in figure 5, section 7, 12 and 23 of this report, where the Mascot can be seen to be thickened on the order of 100 feet by dilatation. How far compensation extends upwards in the Mascot apparently depends on many variables, but in most places it seems to die out a few hundred feet above the Kingsport and Mascot contact; locally, however, it may extend to the unconformity (fig. 5, sec. 23).

Applying the concept of solution thinning and collapse to the previously published (Oder and Miller, 1945, table 2) detailed sections in the Mascot-Jefferson City district by utilizing the technique of Hoagland, Hill and Fulweiler (1965, fig. 2) of selection of a dolomite zone below the R and S interval as a datum brings out the striking similarity between figure 6A and the Oder and Miller sections (fig. 6B). This similarity suggests that solution thinning without apparent collapse has played an important role on a district wide basis and that detailed measurements of intervals between key beds are relatively unimportant because for the most part constant intervals are not maintained between key beds. Because it is difficult to assess the intensity of solution thinning in any given limestone section, a determination of the true original thickness of the Kingsport is not possible. It can only be assumed that the thickest limestone section is nearest to the original thickness. Thickness of the Kingsport Formation ranges from 214 to 350 feet in the limestone phase and from 150 to 290 feet in the collapse breccia phase.

Subsurface studies by zinc company geologists have indicated that locally chert is an important element associated with collapse breccias. It appears to have been concentrated as an insoluble residue within the breccia zone by solution of limestone and to have been directly precipitated (Hoagland, Hill and Fulweiler, 1965, p. 708). Secondary silicification ranges from minor replacement of limestone wall rock to massive chertification of large breccia bodies (Oder and Ricketts, 1961, p. 15). Similar occurrences have been noted in surface exposures, where irregularly shaped white weathering porcellaneous chert masses up to 12 feet thick have been found within breccia bodies (fig. 5, secs. 20 and 23). Although the main mass of secondary chert is confined to the breccia bodies, thin veinlets of chert can be seen to radiate outward many feet from the mass along dilatation openings.

Collapse breccia bodies are obviously secondary features initiated long after the deposition of the Kingsport Formation and Mascot Dolomite. Because of limited exposures it is not practical to attempt to map these structures separately on the surface. However, the contact between the Kingsport and Mascot in these bodies is taken at the place where there is an abrupt change from limestone or medium to coarsely crystalline dolomite typical of the Kingsport to a breccia zone composed of angular fragments of silt to very-finely crystalline dolomite characteristic of the Mascot.

Crystalline dolomite phase

In all fault belts north of the Saltville thrust fault, there is a gradual change in the Kingsport Formation along strike to the northeast from limestone and crystalline dolomite to dominantly medium to coarsely crystalline dolomite. The crystalline dolomite phase may contain the same three rock types--limestone, silty to very-finely crystalline dolomite and medium to coarsely crystalline dolomite--described under the limestone phase. However, limestone is usually not present, but may occur as thin zones or irregular areas, laced with coarse dolomite rhombs. Silty to very-fine crystalline dolomite does occur in thin zones but its overall frequency is somewhat less. The most prominent rock of this phase is medium to coarsely crystalline massive bedded dolomite. Color may be uniformly medium gray, but is usually mottled light gray and medium gray. Mottling seems to be due to partial or complete filling by white dolomite of irregularly spaced vugs or to the occurrence of white chert both as void fill and as matrix material. Chert matrix dolomite is an extremely common rock type.

Chert is a prominent constituent of the crystalline dolomite phase. In addition to the primary and penecontemporaneous cherts described under the limestone phase, the irregularly shaped white porcellaneous secondary chert found in or near breccia bodies is abundant. This white porcellaneous chert can occur in any given section as matrix fill, in small patches, or as irregularly shaped chert masses from inches up to several feet thick. Although this type of chert is ubiquitous its abundance is erratic, and it tends to change stratigraphic position from section to section (fig. 5). It is not unusual to trace in a single outcrop the transition from dolomite to an irregularly shaped chert mass and back to dolomite. Its mode of occurrence suggests that it accompanied dolomitization and continued to develop after dolomitization was largely complete.

Thickness of the crystalline dolomite phase of the Kingsport Formation ranges from 252 to 325 feet. In general, it tends to decrease in thickness toward the northeast along strike in the several fault belts.

Mascot Dolomite

The redefined Mascot Dolomite includes all beds from the unconformity at the top of the Knox Group down to the top of R bed of Crawford (1945) or the 82-28-115 bed of Oder and Miller (1945). In the Thorn Hill section the formation includes units 481 to 687 of Hall and Amick (1934, p. 206-214) and in the Lee Valley section it includes units 244 to 315 of Rodgers and Kent (1948, p. 26-32).

In contrast to the Kingsport Formation, in which limestone or medium to coarsely crystalline dolomite forms the major lithologic elements, the Mascot Dolomite is composed dominantly of silty to very-finely crystalline dolomite with only minor intercalation of limestone and medium to coarsely crystalline dolomite. The silty to very-finely crystalline dolomite occurs in beds from one inch up to one foot thick, that internally may be entirely structureless or may exhibit a variety of features, such as lamination, banding or mottling. Color is usually light gray, however, it is not uncommon in the northeasternmost sections of most fault belts for parts of the formation to be grayish red. The grayish red color can occur in any part of the Mascot, but it is more prevalent in the upper half of the formation, where its intensity may range from faint banding or mottling to a solid red zone (fig. 5). Some red zones seem to persist along strike for several miles, others are inconsistent and occur only locally.

Numerous thin key beds have been recognized by zinc company geologists (fig. 4) especially in about the lower 200 feet of the redefined Mascot Dolomite. Most of these units have been described by Oder and Miller (1945) and Crawford (1945) and they include such things as dark dolomite beds, chert nodule zones, oolitic chert and sandstones. Many of these units are regionally persistent and can be recognized in well exposed surface sections. However, of equal importance as key units are distinctive algal stromatolite beds that occur rather abundantly throughout the upper three-fourths of the Mascot (fig. 5). These beds are important because they are regionally persistent, easily recognized and are considerably thicker, thus easier to find than the thin key units previously described.

In contrast to the dominant silty and very-finely crystalline light gray dolomite of the Mascot Dolomite, algal stromatolite beds are brownish gray, some emit a petroliferous oder when freshly broken, and dolomite within the bed ranges from very-finely to medium crystalline. The type of stromatolite characteristic of these units is the SH-V of the Logan, Rezak, and Ginsburg (1965) geometric classification. These stromatolites are discrete forms, composed of a series of vertically stacked hemispheroidal laminae in which each succeeding lamina does not reach the base of the previously formed laminae. Thus they form crudely column-shaped elements from one-fourth to one inch in diameter. The columnal bodies are composed of brownish-gray commonly vuggy, finely to medium crystalline dolomite set in a ground mass of very finely to finely crystalline olive gray slightly argillaceous dolomite. This difference in grain size and clay content is readily apparent in freshly broken surfaces because it gives the rock a distinctive mottled appearance. Thousands of the SH-V elements occur in laterally continuous, stratum-like growth layers from one inch to three feet thick. Where environmental conditions favored continual vertical development of SH-V, they have accumulated in massive units that are regionally persistent up to 25 feet thick.

The importance of algal stromatolites as rock builders in the Mascot Dolomite has been overlooked. The SH-V stromatolite forms about 20 percent of the total thickness of the Mascot, and the SH-C stromatolite, described under the Kingsport Formation form approximately another 5 percent.

Sandstone beds from a fraction of an inch up to 14 feet thick are important elements throughout much of the Mascot Dolomite. Their usefulness as key beds have been stressed by Oder and Miller (1945). One sandstone bed from 184 to 215 feet above the base of the redefined Mascot in the Mascot-Jefferson City zone district was thought to be distinctive because it had a matrix of white chert (Oder and Miller, 1945, p. 5-6). Analysis of previously published detailed sections plus data from the present stratigraphic study points up that sandstone with a chert matrix can occur throughout the Mascot Dolomite (fig. 5) as well as in the Kingsport Formation and part of the Chepultepec. Thus the difficulty of identifying a certain thin sandstone bed as the same unit regionally is complicated by the fact that these beds have no particular identifying character that assures their recognition. Only when they are used in conjunction with other key beds do they become particularly useful. However, one sandstone bed because of its thickness, which ranges from 7 to 14 feet, does appear to have significance as a key bed over part of the area. It occurs in the same zone as the chert matrix of Oder and Miller, but its distribution is limited to the northeasternmost sections in each fault belt (fig. 5).

Although chert is abundant in the Mascot Dolomite, it is not uniformly distributed throughout the formation. As in the Kingsport Formation, the occurrence and distribution of chert are closely related to the early depositional environment and partly to later events. A small portion of the total chert of the Mascot is composed of (1) primary cherts, such as nodules, (2) penecontemporaneous cherts, that have replaced and preserved in detail structures such as oolites and intraformational conglomerates and (3) later cherts that have replaced parts of breccia bodies or medium to coarsely crystalline dolomite beds. The most abundant cherts are the penecontemporaneous cherts that have replaced algal stromatolite beds. Almost all of the SH-C stromatolites are silicified; however, the SH-V stromatolites which form the bulk of the stromatolites in the Mascot are not uniformly silicified. It is not uncommon for an SH-V zone from 1 to 25 feet thick to be completely silicified and persist laterally for several miles or the same zone may be silicified in one section and not at all in an adjacent section. This is particularly well shown between sections 19 to 23 of figure 5. Even though regionally individual SH-V units are not uniformly silicified, stromatolite zones are so abundant in the Mascot that in any particular section enough units are silicified so that on a regional basis the Mascot does contain abundant chert.

The color of chert may be white as banded and mottled of various shades of gray. Orange chert is moderately abundant in sections where grayish red dolomite is common.

The Mascot Dolomite has a wide range in thickness both locally and regionally. This range is dependent upon two major factors: (1) the reaction of the Mascot to solution thinning in the Kingsport Formation and (2) erosion associated with the unconformity at the top of the Mascot. Because the Mascot tends to thicken by dilatation as it collapses into void space created by solution thinning of the Kingsport, an approximation of its true thickness can only be gained in sections where solution is at a minimum in the Kingsport. Thus, care must be exercised in comparing thickness data on a local or regional scale.

In all fault belts the Mascot Dolomite thins along strike to the northeast. This thinning is not a sedimentary feature, rather it is related to regional beveling by erosion of the Mascot during development of the unconformity at the top of the formation. The absolute amount of beveling is difficult to determine because of the development of paleokarst topography with local relief ranging from 50 to about 200 feet. However, if the thickest apparently non-dilated section of Mascot of 672 feet, from the southwestern part of the Wallen Valley fault belt is compared to the thickest apparently non-dilated section of 437 feet in the northeastern part of that same belt, there is a regional beveling of 295 feet or about 4 feet per mile. In the same fault belt, a comparison of the thickest section, 672 feet, with the thinnest section of 255 feet measured near section 25, but not illustrated, indicates that a total of 417 feet of rocks was locally removed during the erosion interval.

REFERENCED SECTIONS

Although the Kingsport Formation and the Mascot Dolomite are distinct lithologic units, post depositional dolomitization and solution thinning of limestone in the Kingsport have fundamentaly altered their normal contact relationship. Thus, from section to section the contact may be marked by a change from limestone to silty and very finely crystalline dolomite, or by a change from medium and coarsely crystalline dolomite to silty and very fine crystalline dolomite, or by a breccia zone. Because of this variability, it seems best to designate a series of reference sections including both formations where all phases of their relationship can be observed, rather than have a single type section for each formation. The Lee Valley, Thorn Hill and Davis Creek sections are a good representation of the limestone phase, the Clinch River East shows the relationship in a breccia body, and the Clinch River West and Mulberry Creek sections are typical of the crystalline dolomite phase (fig. 5).

MAPPING TECHNIQUES

Carbonate of the Knox Group characteristically weathers to form an upland terrane composed of moderately steep sided hills and disconnected ridges with nearly flat or gently rounded tops. The Knox upland, which forms a laterally continuous belt parallel to regional strike, rises from 100 to 600 feet above the bounding lowlands produced from weathering of the underlying Cambrian Conasauga Group and the overlying Middle Ordovician limestone and shale. Throughout the upland, dolomite weathers to a cherty clay residuum, which forms a nearly continuous deep mantle over the entire area. Outcrops of bedrock with the exception of the Mascot Dolomite are mostly confined to deep valleys cut perpendicular to strike, road cuts, or to steep stream cut banks. Continuous well exposed sections showing more than a hundred feet of rock are rare, but isolated outcrops exposing a few feet of rock are common. Because of the lack of laterally continuous exposures, mapping should only be accomplished through careful analyses of all isolated bedrock exposures and the residuum. Strike and dip of contacts thus located are projected laterally and adjusted to the topography in accordance with insolubles in the residuum. Creep of residual material down hill slopes presents a special problem by introducing errors in location; because of that problem, mapping of residuum is best accomplished on the hill crest region of the Knox terrane. The Knox terrane is well suited to this mapping method because much of it is formed by moderately steep sided discontinuous nearly flat topped ridges, whose main crestline trend parallels regional strike of the bedrock but with subsidiary transverse spurs that transect much of the Knox. Small hills rising above the general level of the ridge crest usually attest to the accumulation in the residuum of material resistent to erosion. Thus the abundant chert of the Kingsport Formation tends to form a discontinuous low set of hills or minor ridges flanking the main Knox upland.

Where bedrock exposures are fairly continuous, the lower contact of the Kingsport Formation with the Chepultepec Dolomite is distinct, and is marked by an abrupt change from a thick sequence of silt to very finely crystalline dolomite typical of the Chepultepec to medium or coarsely crystalline dolomite typical of the Kingsport. Where bedrock exposures are not continuous experience has shown that there are reliable criteria for location of the contacts of the Kingsport. Characteristically about the upper 100 feet of the Chepultepec is composed of very light gray dolomite in thin beds, dolomite in the Chepultepec below the light zone is all darker in color, ranging from light olive gray to olive gray. Consequently, one small isolated outcrop of the very light gray dolomite immediately identifies the stratigraphic position as being somewhere in the upper 100 feet of the Chepultepec. Chert is not usually abundant in the upper 100 feet of the Chepultepec, but it is extremely abundant throughout the Kingsport. Thus, the contact is placed in the residuum at the change from non-cherty soil to abundantly cherty soil. Although the Mascot does contain abundant chert, it is not usually abundant near the contact with the Kingsport. The contact between the Kingsport and the Mascot is placed at the change from abundant cherty soil to non-cherty soil. As thus mapped, the Kingsport forms a laterally continuous band of abundant chert. Residuum developed on the Kingsport is characterized by the abundance of chert containing SH-C stromatolites and large irregular blocks of white weathering chert that may contain a rare specimen of the gastropod Lecanospira.

The Mascot Dolomite forms the flanks of the Knox upland; apparently erosion along the flanks of the upland is somewhat greater for outcrops of the Mascot are moderately abundant. In contrast to the limestone or medium to coarsely crystalline dolomite typical of the Kingsport Formation, the predominant bedrock of the Mascot is thin-bedded very light gray dolomite, similar to the upper 100 feet of the Chepultepec Dolomite. Residuum developed on the light dolomite of the Chepultepec contains little chert, in contrast to the residuum developed on the light dolomite of the Mascot, which contains an abundance of banded or mottled irregular chert blocks and masses. Stromatolitic cherts are abundant thoughout much of the Mascot with the SH-C occurring as laminated circular to donut-shaped masses and the SH-V occurring as porous chert masses whose texture resembles that of a sponge. In a few local areas massive chert zones in the Mascot coalesce with the Kingsport to obscure the contact between the formations. If bedrock of the Mascot is not exposed in these local areas, the contact is projected through the chert zone by utilizing the thickness of the Kingsport.

The unconformable contact between the Mascot Dolomite and rocks of Middle Ordovician age is distinct, and outcrops are abundant. Erosion accompanying the development of the unconformity produced an irregular surface on the Mascot with local relief of as much as 200 feet. Because of this relief its trace tends to be an irregular line, thus in order to be accurately mapped, it has to be carefully walked out. The unconformity is usually marked by the occurrence of a basal Middle Ordovician conglomerate composed of dolomite and angular chert fragments derived from weathering of the Mascot. Bedded dolomite is not an exclusive feature of the Mascot for as much as 20 feet of argillaceous yellowish-weathering dolomite can occur above the basal conglomerates.

Utilizing the mapping techniques just described, it was determined early in this study that the tripartite subdivision of the upper part of the Knox Group into Longview, Kingsport and Mascot Dolomite could not be mapped with confidence. Instead, a two-fold subdivision termed the Longview and Kingsport Dolomite undivided and the Mascot Dolomite was used (Harris and Miller, 1958; Harris and Miller, 1963). Brent (1963) extended the same two map units into the Clinchport quadrangle, Virginia. As stratigraphic studies progressed, the realization grew that the map units of Longview and Kingsport undivided and Mascot did not match the concept of these formations as used by Oder and Miller (1945) and Bridge (1956). As an expediency until enough stratigraphic information could be compiled to make a judgement on whether or not a redefinition of the upper subdivision of the Knox was warranted, the terms Longview Dolomite and Newala Dolomite were used in several quadrangles in southwest Virginia and east Tennessee (Englund, Smith, Harris, and Stephens, 1961; Harris and Stephens, 1962; Harris, 1965a; Harris, 1965b). The terms Longview and Kingsport undivided of the earlier reports and the term Longview of later reports are equivalent to the redefined Kingsport Formation of this report (fig. 2). The terms Mascot or Newala as used in these reports are the equivalent of the redefined Mascot Dolomite of this report. That the redefined Kingsport and Mascot are recognizable and mappable subdivisions of the upper part of the Knox Group is illustrated by the fact that these units have been recognized and mapped in widely separate areas (fig. 1).

CONCLUSION

For many years the terms Longview Dolomite, Kingsport Formation, and Mascot Dolomite have been used as subdivisions of the upper part of the Knox Group. Despite the unanimity in terminology, there has been an almost complete lack of unanimity as to what rocks should be assigned to each formation. This lack of agreement did not arise from the desire of different authors to assign different rocks to each formation, rather it largely resulted from the fact that the original boundaries of the formations were not recognizable natural stratigraphic breaks, but were artificial breaks based on recognition of fossil zones or thin key beds. Thus, attention was diverted from rock units to minor elements within the units; if these keys were not recognized the limits as used by the original authors (Oder and Bridge) were not recognized. Experience has shown that most geologists have not attempted to map subdivisions of the upper part of the Knox based on fossil zones and thin key beds, simply because of the difficulty in recognition of these minor elements. This has contributed heavily to the fact that only limited progress has been made toward a regional understanding of the basic stratigraphy and processes that have materially affected these rocks. It seems reasonable to redefine the present subdivisions so that they coincide with recognizable natural gross rock units and to use key beds and fossils as tools to aid in the study of these units. The upper Knox is readily divisible into two major lithologic sequences--a limestone and medium to coarsely crystalline dolomite unit overlain by a silt to very-finely crystalline dolomite sequence. Accordingly, it is proposed to abandon the term Longview Dolomite because it has been used as a fossil zone and not a rock unit, to redefine the Kingsport Formation to include the limestone and medium to coarsely crystalline dolomite sequence, and to redefine the Mascot Dolomite to include the silt to very finely crystalline dolomite sequence from the top of the Kingsport to the unconformity at the top of the Knox Group.

REFERENCES CITED

Allen, A. T., 1947, The Longview Member of the Kingsport Formation: Jour. Geology, v. 55, p. 412-419.

Brent, W. B., 1963, Geology of the Clinchport quadrangle, Virginia: Virginia Div. of Mineral Resources, Rept. Inv. 5, 47 p.

Bridge, Josiah, 1945, Geologic map with stratigraphic sections of the Mascot-Jefferson City zinc mining district: Tennessee Division of Geology.

_____ 1955, Disconformity between Lower and Middle Ordovician series at Douglas Lake, Tennessee: Geol. Soc. America Bull.,, v. 66, p. 726-730.

_____ 1956, Stratigraphy of the Mascot-Jefferson City zinc district, Tennessee: U. S. Geol. Survey Prof. Paper 277, 76 p.

Brokaw, A. L., and Jones, C. L., 1946, Structural control of ore bodies in the Jefferson City area, Tennessee: Econ. Geology, v. 41, p. 160-165.

Butts, Charles, 1940, Geology of the Appalachian Valley in Virginia: Virginia Geol. Survey Bull. 52, pt. 1, 568 p.

Callahan, W. H., 1964, Paleophysiographic premises for prospecting for strata bound base metal mineral deposits in carbonate rocks: In Symposium on mining geology and base metals, Cento, Ankara, p. 191-248.

Campbell, M. R., 1894, Description of the Estillville sheet [Ky.-Va.-Tenn.]: U. S. Geol. Survey Geol. Atlas, Folio 12.

Cooper, B. N., 1945, Industrial limestones and dolomites in Virginia: Clinch Valley district: Virginia Geol. Survey Bull. 66, 259 p.

Cooper, B. N., and Prouty, C. E., 1943, Stratigraphy of the Lower Middle Ordovician of Tazewell County, Virginia: Geol. Soc. of America Bull. v. 54, p. 819-886.

Crawford, Johnson, 1945, Structural and stratigraphic control of zinc deposits in east Tennessee: Econ. Geology, v. 40, p. 408-415.

Currier, L. W., 1935, Structural relations of southern Appalachian zinc deposits: Econ. Geology, v. 30, p. 260-286.

Dunlap, J. C., and Rodgers, John, 1945, Geologic map of the Mosheim anticline, Green County, Tennessee: U. S. Geol. Survey Strategic Minerals Inv. Preliminary Map.

Englund, K. E., Smith, H. L., Harris, L. D., and Stephens, J. G., 1961, Geology of the Ewing quadrangle, Kentucky and Virginia: U. S. Geol. Survey Geol. Quad. Map GQ-172.

Gordon, C. H., 1924, Occurrence and distribution, in Marble deposits of East Tennessee: Tennessee Div. Geol. Bull. 28, pt. 1, p. 15-86.

Hall, G. M., and Amick, H. C., 1934, The section on the west side of Clinch Mountain, Tennessee: Tennessee Acad. Sci. Jour., v. 9, p. 157-168, 195-220.

Harris, L. D., 1960, Drowned Valley topography at beginning of Middle Ordovician deposition in southwest Virginia and northern Tennessee: in U. S. Geol. Survey Prof. Paper 400-B, p. B166-B189.

______ 1965a, Geologic map of the Wheeler quadrangle, Claiborne County, Tennessee: U. S. Geol. Survey Geol. Quad. Map GQ-435.

______ 1965b, Geologic map of the Tazewell quadrangle, Claiborne County, Tennessee: U. S. Geol. Survey Geol. Quad. Map GQ-465.

Harris, L. D., and Miller, R. L., 1958, Geology of the Duffield quadrangle, Virginia: U. S. Geol. Survey Geol. Map GQ-111.

Harris, L. D., and Miller, R. L., 1963, Geology of the Stickleyville quadrangle, Virginia: U. S. Geol. Survey Geol. Map GQ-238.

Harris, L. D., xxxd Stephens, J. G., and Miller, R. L., 1962, Geology of the Coleman Gap quadrangle, Tennessee and Virginia: U. S. Geol. Survey Geol. Quad. GQ-188.

Hayes, G. W., 1894, Ringgold atlas sheet [Ga. and Tenn.]: U. S. Geol. Survey Atlas, Folio 2.

Hoagland, A. D., Hill, W. T., and Fulweiler, R. E., 1965, Genesis of the Ordovician zinc despsits in East Tennessee: Econ. Geology, v. 60, p. 693-714.

Keith, Arthur, 1895, Description of the Knoxville sheet [Tenn.-N.C.]: U. S. Geol. Survey Geol. Atlas, Folio 16.

______ 1896, Description of the Morristown sheet [Tenn.]: U. S. Geol. Survey Geol. Atlas, Folio 27.

Kendall, D. L., 1960, Ore deposits and sedimentary features, Jefferson City mine, Tennessee: Econ. Geol. v. 55, p. 985-1003.

______ 1961, Ore deposits and sedimentary features in Tennessee: Econ. Geol. v. 56, p. 1137-1138.

Laurence, R. A., 1939, Origin of the Sweetwater, Tennessee, barite deposits: Econ. Geol. v. 34, p. 190-200.

______ 1944, An early Ordovician sinkhole deposit of volcanic ash and fossiliferous sediments in East Tennessee: Jour. Geol. v. 52, p. 235-249.

Logan, B. W., Rezak, Richard, Ginsburg, R. N., 1964, Classification and environmental significance of algal stromatolites: Jour. Geol. V. 72 p. 68-83.

Miller, R. L., and Brosgé, W. P., 1954, Geology and oil resources of the Jonesville district, Lee County, Virginia: U. S. Geol. Survey Bull. 990, 240 p.

Miller, R. L., and Fuller, J. O., 1954, Geology and oil recourses of the Rose Hill district--the fenster area of the Cumberland overthrust block--Lee County, Virginia: Virginia Geol. Survey Bull. 71, 383 p.

New Jersey Zinc Company, 1966, Flat Gap Mine, Treadway, Tennessee: Guidebook in conjunction with Symposium on Genesis of Stratiform Lead-Zinc-Barite-Fluorite deposits, sponsored by U.N.E.S.C.O., Soc. Econ. Geol. and International Union Geol. S. C., United Nations, New York.

Newman, M. H., 1933, The Mascot-Jefferson City zinc district of Tennessee: International Geol. Congress, Guidebook 2, p. 152-161.

Oder, C. R. L., 1934, Preliminary subdivisions of the Knox Dolomite in East Tennessee: Jour. Geol. v. 42, p. 469-497.

______ 1958, How American Zinc's Tennessee DMEA program proved 35,000,000 tons of ore: Mining World V. 20, p. 50-53.

Oder, C. R. L., and Hook, J. W., 1950, Zinc deposits of the Southeastern States, in Snyder, F. E., ed., Symposium on mineral resources of the Southeastern United States, 1949, Proc. p. 72-87: Knoxville, University of Tennessee Press.

Oder, C. R. L., and Miller, H. W., 1945, Stratigraphy of the Mascot-Jefferson City zinc district [Tenn.]: Am. Inst. Min. Met. Eng. Tech. Pub. 1818, 9 p., ibid Trans. v. 178, p. 223-231, 1948.

Oder, C. R. L., and Ricketts, J. E., 1961, Geology of the Mascot-Jefferson City zinc district, Tennessee: Tennessee Div. Geology Rept. Inv. 12, 29 p.

Purdue, A. H., 1912, The zinc deposits of northeastern Tennessee: Tennessee Geol. Survey Bull. 14, 69 p.

Ridge, J. D., 1968, Comments on the development of ore-bearing structure of the Mascot-Jefferson City district and on the genesis of the ores contained in them: Institution of Mining and Metallurgy Trans., section B, p. B6-B17.

Rodgers, John, 1943, Geologic map of Copper Ridge district, Hawkins, Hancock, and Grainger Counties, Tennessee: U. S. Geol. Survey Strategic Mineral Inv. Preliminary Map.

_____ 1953, Geologic map of east Tennessee with explanatory text: Tennessee Div. Geol. Bull. 58, pt. 2, 168 p.

Rodgers, John, and Kent, D. F., 1948, Stratigraphic section at Lee Valley, Hawkins County, Tennessee: Tennessee Div. Geology Bull. 55, 47 p.

Safford, J. M., 1869, Geology of Tennessee: 550 p., Nashville.

Secrist, M. H., 1924, Zinc deposits of East Tennessee: Tennessee Div. Geology Bull. 31, 165 p.

Spivey, R. E., 1966, Geology of the ore bearing formation and genesis of the ore in the zinc mines, United States Steel Corporation. Jefferson City, Tennessee: Guidebook in conjunction with symposium on Genesis of stratiform Lead-Zinc-Barite-Fluorite deposits, sponsored by U.N.E.S.C.O., Soc. Econ. Geol. and International Union Geol. S.C., United Nations, New York.

Ulrich, E. O., 1931, Origin and stratigraphic horizon of the zinc ores of the Mascot district of east Tennessee:(abst): Washington Acad. Sci. Jour. v. 21, p. 30-31.

Wedow, Helmuth, Jr., and Marie, J. R., 1964, Statistical analysis of solution - collapse structure [abst]: Geol. Soc. America Spec. Paper 76, p. 262.

Wedow, Helmuth, Jr., and Marie, J. R., 1965, Correlation of zinc abundance with stratigraphic thickness variations in the Kingsport Formation, west New Market area, Mascot-Jefferson City mining district, Tennessee, in U. S. Geol. Survey Prof. Paper 525B, p. B17-B22.

68-119

(200) U.S. Geological Survey