

THE MINERALS OF IOWA

A photograph of a geological quarry. In the foreground, three people are examining large rock specimens. One person on the left is wearing a blue plaid shirt and a cap, leaning over a large rock. A person in the center is wearing a brown jacket and a straw hat, kneeling and looking at a rock. A person on the right is wearing a light blue shirt and a dark cap, leaning over a rock. In the background, a fourth person is standing against a large, layered rock wall. The sky is clear and blue.

by

Paul J. Horick

Geologist, Iowa Geological Survey

edited by

Otto Knauth and Samuel J. Tuthill

Iowa Geological Survey Educational Series 2

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FOREWORD

In the fall of 1969 I called upon the staff of the Iowa Geological Survey to tell me the research projects they felt were most urgently needed by the citizens of Iowa. In 1969 the discussions of environmental concerns by society were nearing an intensity bordering on frenzy. Geology, hydrology, and physical geography are all responsibilities of the Survey as mandated by the 1897 law founding the agency, and they are also fundamental data if the environmental impact of man's activities is to be assessed. It therefore seemed somewhat strange for Paul Horick to suggest a book on the subject of Iowa's minerals. This was comparable to suggesting that a literature faculty take time out from its considerations of and teachings on Milton's sources, Shakespeare's political implications, or Tennyson's rhyme scheme to prepare a lecture on the English alphabet.

It took only a few months of reviewing the letters from teachers, students, and people possessed of a curiosity to convince me that a basic book on the minerals of Iowa was needed.

Paul has spent several years investigating the minerals of Iowa, the localities where they can be obtained, and the characteristics by which they can be identified. His has been more than an assignment of work. Like all good science, it has not only the stamp of professional competence, but also the air of the work of an amateur in the true Greek sense of the word.

It is our objective that the final product is as devoid of technical jargon as possible. Paul has worked closely with the editors. Otto Knauth's distinguished career as feature writer for the Des Moines Register prompted us to ask him to work on this project. The three of us sincerely hope we have gotten this into English that every interested person can work with.

Paul, Otto, and I have all collected minerals for the sheer fun of it. It is our most fervent hope that this book will be the door by which some future "rockhounds" enter the state of being curious about the earth's building blocks.

Samuel J. Tuthill
Director and State Geologist
Iowa Geological Survey
Iowa City
September 1973

AUTHOR'S PREFACE

This book is designed to fill a critical educational gap. No such report on Iowa minerals has previously been available. It is hoped this work will be useful to the students, the beginning and the advanced amateur mineral collectors, and the teachers of Iowa.

It is impossible to tell here the whole story of the minerals that occur in Iowa. New information is constantly evolving as man digs and probes the earth. Whenever a quarry is opened or an old one deepened, a ledge of stone blasted, a test core drilled, a mine shaft sunk or a gravel pit dug--additional mineral discoveries may be made. There will always be more to learn and enjoy in the fascinating pursuit of mineral collecting.

In this respect Iowa has much to offer the collector. In this book I have only skimmed over some of the locations where minerals have been found in the past.

During this study I have been privileged to meet and work with a large number of fine people. I particularly wish to acknowledge the help of Dr. George R. McCormick for assisting with mineral identification, X-rays and chemical analyses of the more difficult specimens; Donald L. Koch, Fred H. Dorheim, Dr. John H. Carman, Dr. Richard A. Hoppin, and Jack L. Gilmore for numerous discussions and verifications of minerals; Ed Hix, Mary McNamar, Dr. Howard R. Shanks, Dean Anderson, and Hugh L. Carroll for mineral locations; and Don Roberts for photographic assistance. I obtained useful information on the minerals of the coal strip mines around Oskaloosa and Knoxville from John Phipps of the Iowa State Historical Museum. Dr. Jeffry Schabillon provided information on petrified wood. My wife Claudia and my children Jon and Joan spent many hours checking mineral locations with me. John Knecht drafted the mineral figures. Otto Knauth and Dr. Samuel J. Tuthill lent their editorial talents to improve the readability of the manuscript. Suzan Stewart and Jean C. Prior served as proofreaders. To all these people I express my gratitude.

I also wish to thank the many quarry, gravel pit and mine operators in Iowa, and many private landowners who showed every courtesy in allowing me on their properties. Several private collectors with extensive collections of Iowa minerals graciously permitted their names to be listed here as persons who would welcome visitors. These are the Dean Anderson, the Joe Groves, the Ed Hix, the Roland Kinzie, Frank A. Masick and Frank A. Masick, Jr., the Ed McNamar and the Howard R. Shanks families.

Finally, a word of appreciation to the thousands of eager rockhounds, mineral collectors, lapidarists and students in Iowa and elsewhere, who by their very numbers, inquisitiveness, and anticipation, precipitated this book.

Paul J. Horick
Iowa Geological Survey
Iowa City
February 1973

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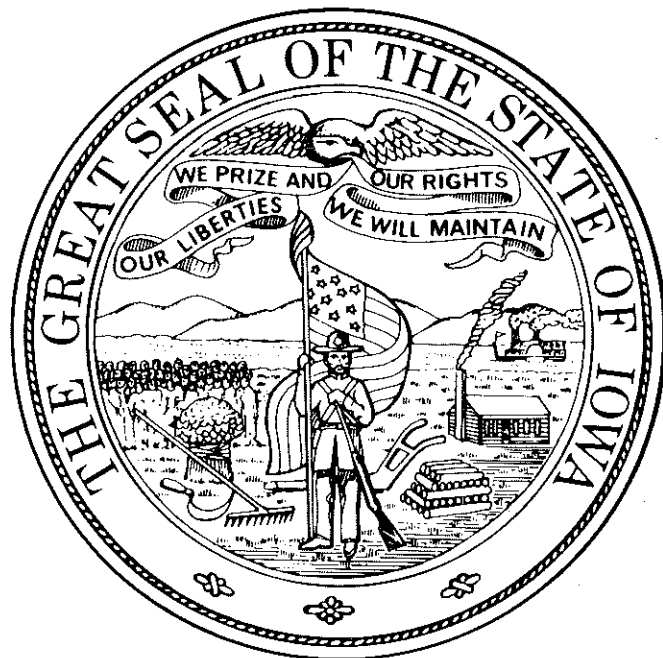
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Introduction

IOWA MINERALS AND THEIR USES

Some domestic activity such as digging for edible roots or building a fireplace probably explains how an Indian woman, the wife of Peosta, a man of the Kettle Chief's village, made a discovery of lead ore. Very likely the woman was attracted by the silvery metallic sheen from the newly broken surfaces of *galena*, a lead sulfide mineral, exposed by a glancing blow of her stone hand ax. The mineral also was quite heavy and she probably recognized it as the ore which her people had been mining elsewhere to barter with the French traders. The year was 1780 and the site was near the mouth of Catfish Creek on the Mississippi River. The land was a fertile wilderness in the territory of the Fox Indians. Further digging no doubt revealed more of the lead ore in the residual soil of the valley or in crevice fillings and veins in the magnesian limestone that formed the bedrock around the village.

Extensive mines were opened during the following years in the vicinity of the present location of Dubuque; also along Tete des Morts River about 12 miles south of Dubuque, and along the Little Maquoketa River near the present village of Durango about six miles northwest of Dubuque. These Indian diggings marked some of the earliest mineral exploration activity in Iowa. However, the French explorers Pierre Radisson and Medard Chouart (Sieur des Groseillers), who apparently visited this area in 1655, about 18 years before Marquette and Joliet first gazed on the Mississippi, reported lead mining by the Mascoutin and other Indian tribes in this vicinity; and Nicholas Perrot, one of the early French traders, operated mines on both sides of the Mississippi River in the Dubuque area beginning about 1690. This was confirmed by Pierre LeSueur, who led a mining expedition to the region in 1699 and observed lead mines on both sides of the great

river. They were still referred to as the mines of Nicholas Perrot. Thus, lead mining is probably the oldest industry in our state.

In 1788 the Indians granted mine-operating rights to Julien Dubuque, an energetic and colorful French-Canadian trader who began the first *serious* white attempt to mine the lead. With a business acumen more characteristic of the Twentieth Century, Dubuque gained complete control of the Upper Mississippi Valley lead mines in the period 1788-1810, and his smelted lead was regularly sold down the river to St. Louis. He was easily the dominant figure in the early development of what has become known as the Upper Mississippi Valley Lead-Zinc district (figure 1). In 1796, as a concession to the Spanish who claimed the land, he named his diggings the "Mines of Spain."¹ Lead mining reached its zenith in the district in 1848 and decreased gradually thereafter. The Upper Mississippi Valley district was the most important lead-producing area in the United States for the period 1830-1870. Just how important is pictured on the Great Seal of the State adopted by the First General Assembly in 1847. Several pigs of lead are stacked prominently in the foreground, with a smelting furnace behind on the banks of the Mississippi.

Zinc

Zinc mining was an outgrowth of lead mining. In the early years the zinc ore was thrown on the mine dumps as valueless, but after zinc became commercially important the dumps were mined. Zinc extraction began on a commercial basis

¹All of the foregoing historical account is summarized in the U.S. Geol. Survey Prof. Paper 309 (1959), The geology of the Upper Mississippi valley zinc-lead district by A.V. Heyl, Jr., A.F. Agnew, E.J. Lyons, and C.H. Behre, Jr., p. 67-68. For additional information the reader is referred to the following reports:

Bain H.F., 1960, Zinc and lead deposits of the Upper Mississippi valley: U.S. Geol. Survey Bull. 294, 155 p., 45 figs., 15 pls.

Calvin, Samuel and H.F. Bain, 1900, Geology of Dubuque County, Iowa: Iowa Geol. Survey Ann. Rept. (1899), v. 10, p. 379-522, 58 figs., 8 pls.

Thwaites, R.G., 1895, Notes on the early lead mining on the Fever (Galena) River region: Wisconsin Historical Collection, v. 13, p. 271-292.

about 1860 in Wisconsin where the deposits were very near the surface. The Iowa production began about 20 years later. There were three types of zinc ores: "drybone" (*smithsonite*, $ZnCO_3$), mixed "drybone" and "jack" (*smithsonite* and *sphalerite*, ZnS), and mixed "jack" and "pyritiferous jack" (*sphalerite* and pyritiferous *sphalerite*, FeS_2 and ZnS). The Iowa zinc production was always a small percentage of the district's total and ceased completely about 1917. Both Wisconsin and Illinois have producing mines today.

Coal

Although the Indians probably knew of the existence of coal and may have used it to a limited extent for fuel long before the white man came to Iowa, the early pioneers were the first to systematically mine the coal beginning about 1840². The first Iowa mining operations were in Scott, Muscatine, Lee, Jefferson, and Van Buren Counties. In the next 20 years the industry grew steadily until it reached a peak production of about nine million tons in 1917. Since then production has declined to 900,000 tons per year. Large reserves remain. At present the industry seems to be on the verge of a comeback. (Note: Coal is organic and although commonly referred to as a "mineral resource," it does not fit the scientific definition of a mineral. However, Iowa coal deposits contain many associated minerals as well as petrified wood that are of interest to collectors.)

Stone

The stone industry in Iowa is now the biggest mineral industry of the state. It began when the pioneers moved into the state during the 1830's and 1840's. Limestone and dolomite and a small amount of sandstone were quarried. Some of the earliest forts were built partly of stone and it was the commonly used material for foundations. Two of the most widely used early Iowa building stones were the LeGrand or Marshalltown stone and the Anamosa stone. Not long after the turn of the century, with the coming of the automobile, there was a clamor for better roads

and the market demand for stone shifted to road metal. Cement is manufactured by a process of drying finely ground limestone. The first portland cement plant in Iowa was opened about 1905 at Mason City.

Gypsum

The famous geologist, David Dale Owen, seems to have been the first person to call attention to the gypsum deposits in Webster County which he saw during a trip by canoe up the Des Moines River in 1849.³ The first gypsum mill was erected near Fort Dodge in 1872.⁴ This industry has prospered to the present and Iowa usually has ranked between second and fourth in annual U.S. production. The discovery and development of deeply buried deposits in rock layers of Mississippian and Devonian age in the southern part of the state in recent years assures large reserves for the foreseeable future.

Clay

The clay industry seems to have had an inconspicuous beginning. The Indians, of course, were the first to use Iowa clays and shales in making their pottery. The earliest settlers were adept at making bricks. Iowa ranked among the top 10 U.S. producers of brick at the beginning of the present century. There are a number of sources of ceramic clay in Iowa. The most often used shales are the Des Moines Series (Pennsylvanian) in southern Iowa, and the Juniper Hill and Sheffield Shales of Devonian age in northern Iowa. Other deposits are in rock or sediment layers of Pleistocene, Cretaceous, and/or Ordovician age.

Iron

Iron ore was known to occur in the Waukon vicinity some 25 years before the first serious attempts to mine it in 1900. This is a brown iron ore (*limonite*) deposit. A local company, the Waukon Iron Company, was formed and a

²Lees, James H., 1909, History of coal mining in Iowa *in* Iowa Geol. Survey Ann. Rept. (1908), v. 19, p. 525.

³Owen, David Dale, 1852, Report on the geological survey of Wisconsin, Iowa and Minnesota: Philadelphia, Lippincott, Grambo & Co., p. 98 and 126.

⁴Wilder, Frank A., 1902, Geology of Webster County: Iowa Geol. Survey Ann. Rept. (1901), v. 12, p. 145.

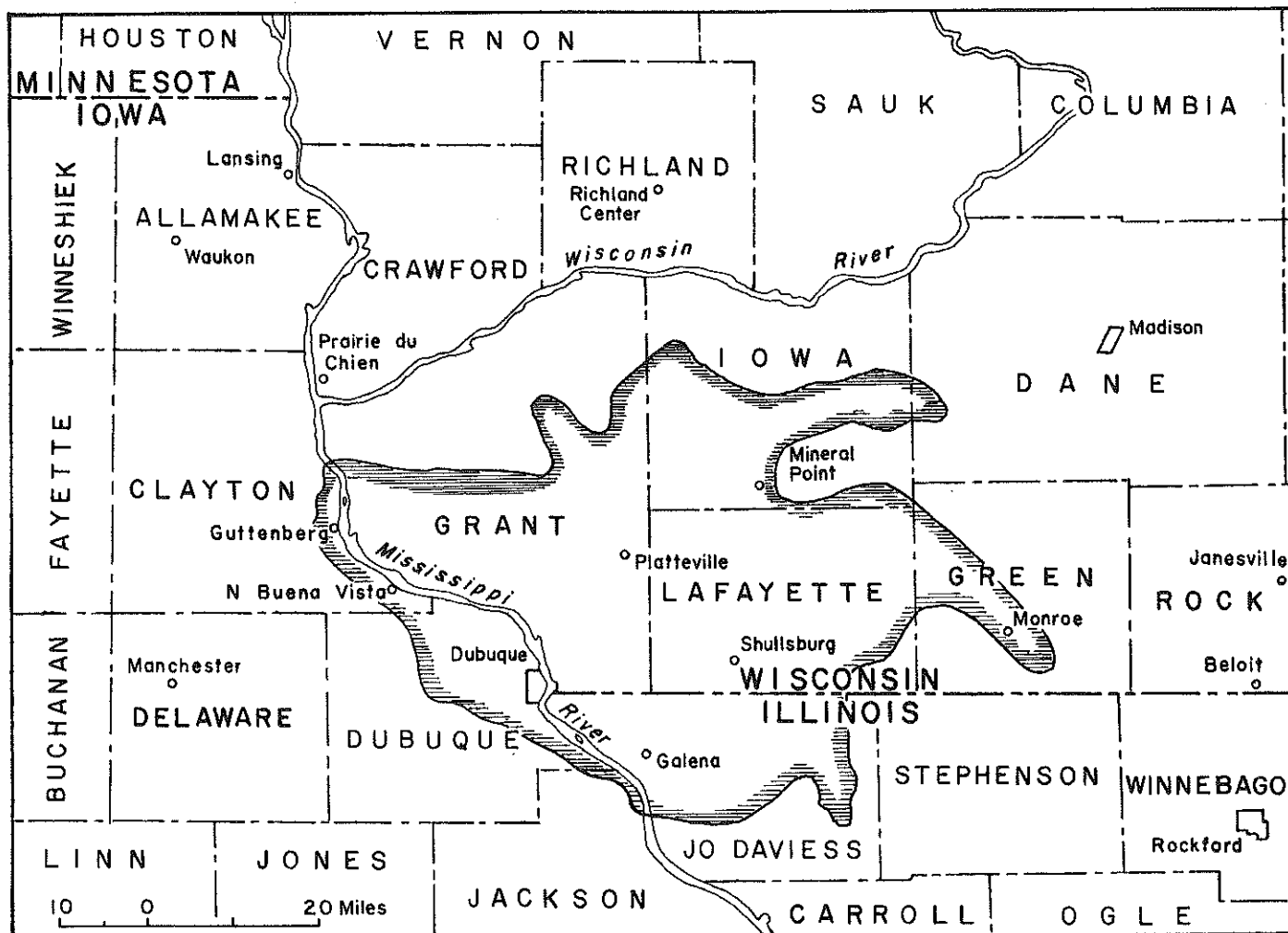


Figure 1 - Index map showing outline of principal mineralized area Upper Mississippi Valley zinc-lead district.

U.S. Geological Survey Prof. Paper 309

concentration plant built. It consisted of a crusher and log washer driven by steam power. Analyses indicated the limonitic deposit to contain, on the average, about 32 percent iron, with some samples ranging as high as 50 percent. The Waukon Iron Company eventually failed, chiefly because of the physical nature of the ore which made the washing treatment unsuccessful and because of the high cost of hauling the ore by wagon to the railroad at Waukon. About 1909 the interests of the local company were acquired by the Missouri Iron Company of St. Louis. After a thorough study of the best method of treating the ore, a larger and more sophisticated plant was completed in 1913. At least 27,000 tons of ore were mined, processed and shipped in the ensuing years until the plant was closed after World War 1. In 1943 the U.S. Bureau of Mines reinvestigated the Waukon deposit, but no further development has taken place. In recent years there has been some geophysical exploration for iron ore in the northwestern and northeastern parts of the state, but no commercial ore bodies have been identified as yet.

Sand and Gravel

A natural resource left by the glaciers that covered Iowa during the last million years is sand and gravel. Nearly three-fourths of Iowa's counties have high-quality deposits of sand and gravel in terraces of the larger streams. The industry started early in the present century when a more permanent system of roads began to be established in Iowa. Some of the major producers are found at Des Moines, Ames, Hawarden, Waterloo, Lake View, and Muscatine. In addition to its construction uses as a concrete aggregate, sand and/or gravel is used for covering rural roads, as a fill material, for lining blast furnaces, for filtration and molding, and for railroad ballast. This industry has had a steady growth and has increased in value over the years.

These, then are the mineral resources found in Iowa. But there are many other minerals, often of no commercial value, also found in the state. Many of these minerals are exquisite in themselves, in crystal form, luster, color, and physical

setting. No words can possibly describe the loveliness of a cluster of delicate, radiating, metallic *millerite* brushes set on and penetrating a group of transparent *calcite* or *quartz* crystals, or the rainbow iridescence of an aggregate of oxidized *pyrite* or *calcite* crystals.

For a reasonable grasp of the subject of mineralogy the beginner should know something about the composition of minerals, how they are put together, their crystal shapes and physical properties. He should also know what tools and other paraphernalia are needed before making collecting trips. These fundamentals will be discussed before the minerals themselves are described.

In general, only the more important and easily accessible collecting locations are described. The mineral enthusiast should keep in mind that a collecting locality eventually may become so popular that good mineral specimens can no longer be found there or that the outcrop may be otherwise destroyed. In that case, you will have to search the surrounding area for other exposures or other localities where the mineral is known or suspected to occur. For example, large and beautiful *barite* crystals occur at the contact of the Maquoketa and Galena Formations at many places in the Dubuque area, but owing to the growth of the urban community, finding suitable exposures is a problem. These field exploration sorties only add to the fun and challenge of mineral collecting. Coal strip mines, which are sources of many minerals and petrified wood, must now be covered and graded when abandoned. Information on operating mines can be obtained from the Iowa Geological Survey at Iowa City or the County Tax Assessor's office in the particular county in which you plan to collect.

An abbreviated table for identifying Iowa minerals is found in Appendix III at the back of this book.

REMEMBER THAT ALMOST ALL COLLECTING SITES ARE ON PRIVATE PROPERTY. COURTESY AND IOWA LAW REQUIRE THAT PERMISSION BE OBTAINED BEFORE YOU ENTER PROPERTY NOT YOUR OWN. YOUR GOOD MANNERS WILL DETERMINE THE RECEPTION THAT YOU AND OTHERS RECEIVE IN THE FUTURE.

CHAPTER I

WHAT MINERALS ARE MADE OF – ATOMS AND MOLECULES

If you visit one of the numerous gravel pits around Iowa or check the boulder piles seen on many Iowa farms, you will observe many different kinds of rocks. Geologists have defined rocks as any naturally occurring aggregate of one or more species of minerals. They also have invented a complex system of naming them. Some of these names are: Granite, syenite, diorite, and gabbro (examples of coarse-grained igneous rocks). Rhyolite, trachyte, andesite, diabase and basalt are the mineralogically equivalent finer-grained igneous rock types. An igneous rock is one that was a liquid within the earth's crust and cooled and solidified directly into rock form from a melt. The classification of igneous rocks is based on their mineralogy and texture (size of crystals).

Sedimentary rocks such as limestone, shale, and sandstone occur in layers that often can be seen exposed in the walls of valleys and in roadcuts and quarries. These rocks were deposited thousands, even millions of years ago, as accumulations of soft mud or sand on the bottom of the seas, streams, or lakes that then covered the region. Ultimately the sediments were compressed or cemented into layers of hardened rock. Fragments of all kinds of sedimentary rocks also can be found weathering out of soils and glacial deposits.

Metamorphic rocks such as marble, quartzite, slate, gneiss, and schist are rocks that originally were igneous or sedimentary and that have been altered by heat and/or pressure. The igneous and metamorphic boulders and cobbles that can be found in most of the state were carried here by the Pleistocene glaciers from Canada, Minnesota, and Wisconsin and dropped across Iowa when the ice sheets melted.

Look closely at all of these rocks—igneous, metamorphic and sedimentary—and you will see that they are formed of grains and masses of various size, shape, color, luster, and hardness. These are the minerals which make up the rocks of the earth. At present there are at least 1,500 known minerals, with new ones being described almost every year. Mineralogists define a mineral as a naturally occurring inorganic

(never having lived) substance that has a characteristic internal arrangement of its atoms and has physical properties that are fixed or vary within a definite range. All minerals are both solid and crystalline. Non-crystalline (amorphous) materials such as coal or natural glass are called mineraloids. The outer surface of crystalline minerals may exhibit symmetrical planes or crystal faces. These occur because of the orderly internal structure of the atoms that comprise the mineral. Light reflected from the many faces of clear *quartz* crystals lining the interior of a geode, for example, show the outward expression of this internal order.

All matter of the earth, inorganic and organic, is composed of *elements*, either by themselves or in combination. Generally, the chemical composition of a mineral can be stated in a formula such as CaCO_3 (*calcite*) which is a compound of the elements calcium, carbon, and oxygen in the ratio of 1-1-3. *Quartz* (SiO_2) is a compound of one part silicon and two parts oxygen. The elements are formed of *atoms*. As far as minerals are concerned, atoms are the smallest constituents and may be considered indivisible because the processes of nature do not split atoms when forming minerals.

The Periodic Table of the Elements lists the 103 elements we have discovered and defined and these, in various combinations, form the minerals of the earth. Each element has a different atomic number and weight. The lighter elements are the most abundant in the earth's outer crust. In fact, oxygen forms more than 90 percent by volume of the elements in the earth's accessible rocks. This oxygen in the crust is bound to the atoms of other elements, chiefly silicon and aluminum, to form the compounds of the rock-making minerals such as *feldspar* and *quartz*. Only eight of the 103 elements are commonly found in the minerals of the earth's crust. The eight, which make up 99 percent (by weight) of the earth's crust, are: oxygen (46.60%), silicon (27.72%), aluminum (8.13%), iron (5.00%), calcium (3.63%), sodium (2.83%), potassium (2.59%), and magnesium (2.09%).

If you are fortunate, you may have seen or collected some large, transparent,

nearly perfect gypsum (*selenite*) crystals from the coal strip mines of southern Iowa or from shale exposures in various other places around the state. How do the elements combine to form such beautiful crystals? First, the elements must be present in a fluid medium—a gas, liquid solution, or melt—in which the atoms are free to move about in all directions. Second, proper conditions of temperature, pressure and room for growth are needed. The atoms in the gas or fluid go from an environment in which they are free to move about into a fixed position in a rigid crystalline framework. The mineral must have a regular, orderly, internal structure to be crystalline. The internal structure depends on *molecules*, which are small groupings of atoms. In the gaseous state the atoms and molecules are constantly moving and have only a slight electrical attraction for each other. In the liquid state the atoms and molecules are in closer contact, but still have no regular internal structure. In the crystalline state, the atoms and molecules are bound together tightly by electrical charges they share. They fall into an orderly, three-dimensional

arrangement which may form the smooth crystal faces of the different minerals when the conditions permit it. But as might be expected, "Mother Nature" has her quirks and perfect crystals are practically never formed. Imperfections are the rule because some atoms are missing, impurities are present, or sufficient room for the growth of a perfect crystal was lacking.

Crystals grow by the addition of their constituent atoms to the previously formed surface. Where room for growth is limited, the crystals soon interfere with one another. This often leads to the growth of earthy or granular masses without crystal faces. Good examples of this crowding of crystals to the point where there is no visible outward expression of the internal molecular arrangement are *quartz* in granite and *calcite* in marble. Many mineral specimens you will find have grown in this kind of environment.

CHAPTER II
CRYSTALS AND THEIR SHAPES

It will help a great deal in identifying mineral specimens if you become familiar with the general shapes of the varieties of minerals to be collected. The external shape of crystals exhibits a symmetry and regularity that can be defined as well as aesthetically appreciated. It has been said that crystals are the flowers of the mineral kingdom. Crystal symmetry is related to the balanced arrangement of the molecules in the interior. All crystals grow in symmetrical patterns. If you can recognize the symmetry of a crystal, you have found an important means of identifying minerals. However, this is often very difficult because no two crystals of the same mineral are exactly alike in the size and shape of their faces, although the angles on corresponding faces (its symmetry) are identical.

There are six crystal systems, named according to their appearance and the arrangement of their axes, planes, and centers of symmetry. Each system is characterized by a special set of crystallographic axes which pass through the center

of the crystal. The six systems have 32 subdivisions or classes and there are many forms and combinations of forms in each class. A form contains all faces in a crystal which have the same numerical relationship to the crystallographic axes. Don't be scared away by the large number of classes and forms to memorize. The form of a well developed crystal may be characteristic enough so that you can identify it by its shape. Even if you can't recognize the class, if you can recognize the crystal system of a mineral, this usually is enough when considered along with other properties, for identification. The six crystal systems are named isometric or cubic, tetragonal, orthorhombic, monoclinic, triclinic and hexagonal. (A seventh system, trigonal, has been accepted by some authorities, but hasn't come into general usage yet in the United States. The pioneer mineralogist James D. Dana recognized two divisions of the Hexagonal System, the Hexagonal Division and the Trigonal or Rhombohedral Division.) They can be distinguished by the differences in symmetry as shown in the illustrations in Appendix IV.

CHAPTER III

PHYSICAL PROPERTIES OF MINERALS

When the Fox Indian woman discovered lead ore along Catfish Creek almost 200 years ago, the qualities that called her attention to it probably were its unusual heaviness and the brilliant metallic reflection from fresh surfaces. Although she didn't realize it, she was using two important physical properties of minerals, specific gravity and luster, to identify her find. Many minerals have certain characteristic properties which can be used to help identify them, such as luster, color, hardness, cleavage and specific gravity.

Luster: Luster is created by the reflection of light from a mineral surface. To illustrate, take a piece of crystalline *quartz* or *calcite* and rotate it in your fingers in a light. Note that the surface of the mineral reflects the light like a piece of glass. In this case, the luster is described as non-metallic, glassy, or vitreous. There are three basic kinds of luster: metallic, submetallic, and non-metallic. Examples of metallic luster are seen on the minerals *silver*, *gold*, *copper*, *galena* and *pyrite*. Their surfaces shine or reflect light like a metal. Metallic minerals are opaque—no light passes through them. A few minerals like *sphalerite* and *rutile* have an imperfect metallic luster and are said to be submetallic. Many adjectives are used in describing the luster of non-metallic minerals, but the most common are: vitreous (glassy), adamantine (brilliant or like oiled glass), resinous (like pine resin), pearly (like the sheen of pearls), silky, greasy and waxy. When no luster is apparent minerals are usually described as dull or earthy. Non-metallic minerals are usually transparent to translucent, at least on their outer edges.

Color: One of the first properties observed about a mineral is its color. The color of minerals with a metallic luster such as galena or pyrite usually doesn't change (except by chemical weathering) and may be enough to identify the mineral. Some non-metallic minerals also have a characteristic color such as yellow (*sulfur*), green (*malachite*) and blue (*azurite*). Most other minerals have a considerable range of colors owing to the presence of inclusions or chemical variants. Thus, care must be taken in using color to identify minerals. This test is best used along with other more definite properties.

Hardness: The atoms in different minerals are bonded together with varying degrees of strength. The tighter the bond the stronger the mineral will be. For example, *graphite* or *muscovite* will easily rub off on your fingers, but *calcite* will not. *Calcite* has a greater hardness than *graphite* or the *mica* minerals. *Fluorite* can be scratched by a knife, but *quartz* cannot. This resistance to abrasion or scratching is called its hardness.

Common objects such as a fingernail, a copper penny, a knife blade, a piece of window glass, and a steel file can be used to test mineral hardness. However, testing in this way will give only the approximate hardness. A standard hardness scale for minerals known as Mohs' Scale of Hardness provides a more definitive basis of comparison. This consists of a series of 10 minerals graded from 1 to 10 according to their hardness as follows:

- | | |
|-------------------------------------|-------------------------|
| 1. Talc | 6. Orthoclase
- file |
| 2. Gypsum - fingernail | 7. Quartz |
| 3. Calcite - penny | 8. Topaz |
| 4. Fluorite | 9. Corundum |
| 5. Apatite - knife blade
- glass | 10. Diamond |

Each higher number on the scale represents a greater degree of hardness.

For the beginning student, the common objects will suffice for identifying

mineral hardness. The hardness of the fingernail is between 2 and 2.5; a copper penny, about 3; a pocket knife, about 5 to 5.5; window glass, 5.5; and a steel file, about 6.5.

Streak: The color of a mark a mineral that is softer than *quartz* leaves when it is drawn across a piece of unglazed white porcelain is called its streak. Since a streak plate has a hardness of about 7, or equal to *quartz*, you won't be able to use it for minerals that have a greater hardness. If no streak plate is available, an unweathered sample of the mineral should be crushed to a fine powder and poured on a piece of white paper to determine its color. The color of the streak of a mineral usually is constant even though the mineral may have great color variation. The streak of *hematite* is always reddish brown although the mineral may range from barn red to dark silver gray. Minerals with a metallic luster usually have a black or dark-colored streak. Non-metallic minerals usually have streaks that are light-colored, white or uncolored.

Cleavage and Fracture: Cleavage is the tendency of a mineral to split so that a smooth, flat surface is formed. This is caused by the internal arrangement of the molecules and atoms. The splitting occurs along the weakest planes. Cleavage is a most important physical property. Many minerals have good cleavage. Descriptions of cleavage are based on its direction, such as cubic (parallel to the six square faces of a cube); octahedral (parallel to the eight triangular faces of an octahedron); rhombohedral (parallel to the six parallelogram faces of a rhombohedron); basal (parallel to the basal plane); prismatic (parallel to the faces of a prism); pinacoidal (parallel to two axes of a crystal, commonly referred to as side-, basal- and front-pinacoids); and on how easily it is formed, such as perfect, distinct, indistinct, in traces, inconspicuous, poor, etc. The direction, angle, and perfection of the cleavage, when present, are different for different minerals, but they are characteristic of specific minerals and thus aid greatly in identification attempts. Some minerals may have only one cleavage plane, for example, as in *mica*. When this is the case, flat planes of breakage will all be parallel and there will be only one orientation for these planes—like the pages of a book. *Calcite* and *galena* have perfect cleavage in three directions, and thus the cleavage planes will have three different orientations. When a mineral does not break along definite cleavage planes, it may fracture in other characteristic ways. Some terms used to describe the fracture of minerals are uneven, rough, irregular, splintery, conchoidal (shell-like), hackly or jagged and earthy.

Specific Gravity: The comparative weight of a mineral may help to identify it. *Barite* looks like *calcite*, but is much heavier than *calcite*. The specific gravity

(Sp.G.) of a mineral is the weight of the sample compared to the weight of an equal volume of water. The Sp.G. depends on the atomic weight of the atoms and their structural arrangement. If the mineral sample is porous or impure, the Sp.G. will be lower than the true value.

You will need an analytical balance to get precise measurements of the Sp.G. of any mineral specimen. But for general purposes, a spring balance is all that will be needed. Very precise Sp.G. values are not often required because when two minerals have very similar Sp.G., other characteristics should be used for identification. To determine the Sp.G., weigh a small sample of the mineral in air and then weigh it suspended in water. The difference in the two readings is the weight of an equal volume of water. Then

$$\frac{\text{Weight in air}}{\text{Loss of weight in water}} = \text{Specific Gravity (Sp.G.)}$$

The Sp.G. of water is 1. Since most minerals have a higher Sp.G. than water, they will sink in water. Although you can determine specific gravity in the field, it is difficult and time consuming there. As you learn to "heft" the weight of minerals as heavy or light compared to other minerals, the characteristic of Sp.G. will become useful as an aspect of field identification.

Tenacity: How a mineral holds together and resists breaking, crushing, bending or tearing is the property of tenacity. Terms used to describe tenacity are: brittle, friable, sectile, malleable, flexible, elastic and tough. A mineral that is fragile and easily broken into fragments is brittle. Most minerals are brittle and can be crushed into a powder fairly easily. A friable mineral crumbles easily. A sectile mineral can be cut into pieces that have smooth surfaces. A malleable mineral can be hammered into thin sheets without breaking. A mineral that will bend without breaking and remain bent is said to be flexible. An elastic mineral bends under stress and returns to its former position when the stress is removed. Tough minerals withstand breakage.

Mineral Aggregates: Various terms are used by mineralogists to describe the structure of different types of masses or aggregates of minerals. Since you will encounter crystalline aggregates more often than you will find individual crystals, it will pay to familiarize yourself with the more important terms and their meanings as follows:

Acicular — Slender, rigid needle-like forms. Example: *millerite* brushes.

Banded — Consisting of alternating layers of different color and/or texture. Example: *chalcedony* (agate), *calcite* (Mexican onyx), *fluorite*.

Bladed — Long flat crystals, somewhat like a knife blade. Example: *selenite*, *epidote*.

Botryoidal — Smooth rounded masses, appearing like a bunch of grapes. Example: *goethite*, *limonite*, *chalcedony*.

Capillary or filiform — Delicate hair-like or thread-like crystals. Example: *millerite*.

Columnar — Composed of slender to thick columns or prisms. Example: *hornblende*, *quartz*, *calcite*, *microcline*.

Crested — Closely packed groups of small tabular crystals projecting at the surface like a tuft of feathers or blades of grass. Example: *barite*.

Dendritic — Branching, fern-like or tree-like forms. Example: *pyrolusite*, *copper*, *gold*.

Equant — Crystals nearly equally developed in every direction. Example: *zeolites*.

Drusy — Coatings or crusts of tiny crystals. Example: *quartz*.

Fibrous — Composed of fibers. Example: *gypsum* (satin spar), *calcite*, *serpentine*, *chrysotile* (asbestos).

Foliated or micaceous — Extremely thin layers that can be separated. Example: *biotite*, *muscovite*, *chlorite*.

Granular — Aggregates of grains, fine to coarse. Example: *calcite* in limestone and marble, *quartz* in some sandstone and quartzite.

Lamellar or tabular — Shaped like plates or leaves that may be straight or curved and occur individually or in groups. Example: *barite*, *calcite*, *selenite* and the micaceous minerals.

Oolitic — Small rounded grains that look like fish eggs. Example: *calcite*, *limonite*.

Radial or stellated — Radiating from a center in all directions. Example: *marcasite*, *goethite*, *millerite*.

Reniform — Rounded (kidney-shaped) masses that may have a radial or concentric internal structure. Example: *hematite*, *malachite*.

Reticulated — Lattice-like or grid-like intergrown crystals crossing one another in various directions. Example: *cerussite*, *stibnite*.

Stalactitic — Icicle-like columns, cylinders or cones. Example: *calcite*, *limonite*, *marcasite*.

Other properties: Some chemical or physical properties of mineral species are useful to the mineralogist attempting to identify specimens. For example, a simple chemical test, that of placing a drop or two of dilute hydrochloric acid on a carbonate mineral, may be of practical use in attempts to identify the minerals *calcite*, *dolomite*, *smithsonite*, and *aragonite*. A few minerals, notably *magnetite* and *pyrrhotite*, are magnetic.

The salty taste of halite and the astringent (vitriolic) taste of *melanterite* are characteristic.

Many sulfide minerals when heated give off a sulfurous odor.

Moistened clay has a distinctive clayey odor.

Talc has a peculiar greasy feel.

Fluorite when heated gives off light

When white light falls on certain minerals such as *calcite*, *quartz*, *opal*, *diamond*, and *pyrite*, a play of rainbow colors may be observed. It is caused by interference of light from thin films or layers of different refractive indices within the mineral or from the outer surfaces. The effect is often breathtakingly beautiful. This is known as iridescence.

If the exposed surface of a mineral, especially metallic minerals like *pyrite*, *galena*, or *hematite*, alters to a different color and luster than the interior, it is said to be tarnished. This is due to formation of thin films, usually oxides, on the surface of a mineral by exposure to air and water. The color change is permanent. *Limonite* (hydrated iron oxide) is one of the most common sources of tarnish.

CHAPTER IV

TIPS ON COLLECTING, FIELD EQUIPMENT AND SAFETY

Your mineral collecting trips will be more successful and fun if you have done some advance study and preparation and have the right equipment without being overburdened. Before making a field trip, you should read as much as you can about minerals, particularly those of the area you are expecting to visit. The selected references listed at the back of this book should be helpful. Look at the photographs in books on minerals in your library, visit museums, and get your more experienced mineral-collecting friends to show you their specimens. A list of museums and private collections that can be visited in Iowa is summarized in Appendix II. In these ways you will become familiar with the characteristics of many minerals and will be able to identify them.

Before starting on your first collecting trip, get specific directions to a mineral location or go with someone who knows where and how to find what you are looking for. Moreover, it is always advisable to take someone with you on your collecting trips because quarries and pits can be very dangerous places. Do not be shy about meeting with rock and mineral clubs. They are full of enthusiastic, helpful people, some of whom will be most happy to help a beginner get started.

The most important piece of field equipment is a geologist's or prospector's hammer which is really a combination hammer and pick. A bricklayer's hammer which has one end tapered, but flat, will serve equally well. A pair of safety glasses or goggles should be worn when using hammers on rocks. Some collectors take along a short cracking hammer and a sledge hammer for breaking hard rocks and opening large concretions. You will find a canvas field collecting bag handy for carrying specimens. Ordinary newspaper can be used to wrap the specimens to keep them from breaking. Use soft facial tissue for wrapping fragile crystals. A small chisel will be useful to dig and pry around minerals embedded in rock. A set of larger chisels, one with a wide end, will be needed for splitting concretions and thin slabs of rock. A pocket knife also is useful for cleaning and prying the more delicate specimens and to test for hardness. You will want a magnifying glass or hand lens of at least 10 power for examining the minerals more closely for crystal shape and

cleavage. A small piece of unglazed white tile can be used to determine the color of the streak. Many collectors like to carry a small plastic dropper bottle of dilute (10 percent) hydrochloric acid to test for calcite and other carbonate minerals. Be careful with the acid. Spills can irritate your skin and eat holes in your clothes. It is a good idea to label the bottle "POISON-ACID."

Take a small notebook and pencil to jot down the precise location of your finds for future reference and return visits. Each specimen should be clearly labeled in the field with adhesive tape, writing the name and location directly on the tape. Some collectors keep a descriptive card file, giving the name of the mineral, collecting location and date, and collector's name. The minerals are boxed and numbered to correspond to a number in the card file. In any event you should develop a system that ensures that you can associate the following information with each of your specimens: mineral name, location of place where it was found, person who found it, and the person who identified it or verified your identification.

You should familiarize yourself with the *Geologic Map of Iowa* and *Stratigraphic Column of Iowa* accompanying this book (in pocket). They are invaluable in understanding the various layers of rock you are working with. The *Mineral Resources Map of Iowa* shows the location of numerous quarries and gravel pits. This map may be ordered from the Iowa Geological Survey (see reading list attached). Topographic maps also show quarries and pits and are useful for plotting the location of minerals you find.

Every collector should know and follow common sense rules of safety. In every case you must ask the landowner's permission to enter his quarry, gravel pit, or farm. He may not only warn you of certain hazards such as blasting times, landslides, high walls, quicksand, abandoned mine shafts, and electric fences, but also may direct you to the best collecting locations. Furthermore, some owners may charge a small fee for collecting on their land, plus an additional fee per pound of minerals taken. Leave all gates as you found them, coming and going, and stay away from livestock. Don't be a litterbug and don't leave your tools in the quarry

or pit. Always take someone with you when you enter a quarry. Many quarry owners require you to sign a visitor's application and release paper. You should stay away from vertical rock faces, avoid machinery whether operating or not, be watchful of all trucks and machinery, and stay out of haul routes. You should wear a construction worker's hardhat, safety glasses, and safety shoes. The yellow, red, blue, and black wires seen in quarries were previously connected to explosives used in blasting. Do not touch them. They might be connected to a charge that did not detonate and you could be the victim of an unfortunate accident.

Durable work clothes are best. I also advise taking along a pair of leather gloves. Certain rocks can be extremely sharp. Carry a first-aid kit and a thermos of water in your car. Rattlesnakes seem to have a liking for rocky areas, particularly in the Mississippi River counties. The best snake-bite preventative is slow, deliberate

movement. Use a stick to disturb the vegetation ahead of you. Snakes are shy animals and if given a chance will usually get out of your way. Get your doctor's advice on what to do if struck by a venomous snake *before* you go into the field.

Be selective in your collecting; don't pick up every mineral specimen in sight. A good collection is based on quality, not quantity. Finally, make it a habit to thank the property owner when you leave the premises.

By observing these simple rules of common sense and courtesy, you will assure that collecting locations will be kept open to you and other collectors who follow. Don't be discouraged if you don't find those gorgeous museum specimens the first few times out. Study, persevere, learn, and appreciate. Eventually some of the prize specimens will come your way. Good luck and have fun, but please be careful.

CHAPTER V

IOWA MINERALS: DESCRIPTIONS, LOCATIONS, AND USES

The scheme of classification of minerals used in scientific books on mineralogy is based on similarities in chemical composition with further divisions made on crystal form, physical properties, and modes of occurrence. In this book the minerals are listed alphabetically. This seems to be the easiest way for the beginning student to find what he is looking for without the need to memorize in which chemical class a species belongs, i.e., whether it is a native element, sulfide, haloid, oxide, carbonate, silicate, phosphate, sulfate, etc. Furthermore, less than 60 minerals are described here compared to 1,000 or more in the comprehensive texts. A broad description of the crystallographic and physical properties of each mineral and common methods of identifying it are given in the first paragraphs. This is followed by a description of collecting localities the author visited or received reliable information on. Brief comments on the uses of the mineral conclude the summaries.

The reader is encouraged to use the selected list of references for additional information on minerals and where they might be found in Iowa.

ANGLESITE (lead sulfate PbSO_4)

Anglesite is a lead mineral found in the zone of weathering of lead ore deposits. Crystallographically it is orthorhombic and occurs in prismatic, tabular and pyramidal crystals and in massive, granular, stalactitic and nodular forms. It is a mineral that forms by the natural chemical breakdown (weathering) of *galena* (PbS) and in turn it weathers to *cerussite* (PbCO_3). The alteration may be in all stages of development, with fresh cores of *galena* surrounded by concentric bands of *anglesite* and covered by a crust of *cerussite*. The massive, earthy variety, forming concentric bands around a core of unweathered *galena* and known as "woody" *anglesite*, is common. Color is usually white or light gray. Crystalline varieties have an adamantine or resinous luster, while the fine-grained, massive varieties are dull. *Anglesite* has a hardness of about 2.5 to 3. It is also very heavy, 6.38 Sp.G. The fracture is conchoidal and brittle. Crystals may be transparent, but massive varieties are opaque. *Anglesite* resembles *cerussite* somewhat; however, *anglesite*, a sulfate,

won't emit bubbles of carbon dioxide (CO_2) in either warm hydrochloric or nitric acid as will *cerussite*. In addition to *galena* and *cerussite*, other minerals associated with *anglesite* are *gypsum*, native *sulfur*, *wulfenite*, *smithsonite*, and a few other rarer types.

Anglesite is not abundant in Iowa, but it can be found by examining weathered pieces of *galena* from the old mine dumps around Durango in Dubuque County and from the old lead prospects in Allamakee County north of Waukon and northwest of Lansing. Some of the lead from the Mineral Creek prospects shows pseudomorphs of *anglesite* after *galena* that probably occurred in combination cube and octahedron forms (plate 1A). Cores of fresh *galena* can be observed inside broken crystals. Pseudomorphs are minerals that have the outward crystal form of another mineral. In this case, *anglesite*, lead sulfate, has the crystal form of *galena*, lead sulfide (see Appendix IV for additional discussion on pseudomorphs).

ANHYDRITE (anhydrous calcium sulfate CaSO_4)

Anhydrite is a compound of calcium and sulfate similar to *gypsum*, but unlike *gypsum* does not contain water or only small amounts. It may alter to *gypsum* by absorbing water. *Anhydrite* usually is gray or white, but may be slightly bluish-gray. The streak is white. Fresh surfaces have a massive, granular, crystalline appearance that look somewhat like crystalline limestone or quartzite. The fracture is uneven. The luster is glassy or pearly. The mineral is transparent to translucent. Crystallization is orthorhombic. There are three good cleavage directions but the mineral usually occurs in cleavable masses (these are generally broken in mining operations). Crystals are not common. The hardness is 3 to 3.5. The Sp.G. is 2.9 to 3.

Anhydrite is not known to occur at the surface in Iowa. It has been found in the deep *gypsum* mine near Sperry in Des Moines County and in deep well drilling samples and diamond drill cores penetrating the Cedar Valley and Wapsipinicon

Formations of Devonian age in the southern and central part of the state. The old Centerville *gypsum* mine in Appanoose County, penetrating the upper part of the Mississippian rocks, also encountered *anhydrite* beds. At present the stockpile of the Sperry mine apparently is the only collecting location in Iowa. You'll need permission to obtain samples.

ANKERITE (Ca(Fe,Mg)(CO₃)₂)

Ankerite belongs to the *dolomite* group of carbonate minerals. It is characterized by more iron than magnesium; whereas *dolomite* contains more magnesium than iron. These minerals are gradational. Intermediate types are called ferroan dolomites. Like *dolomite*, *ankerite* crystallizes in the hexagonal system, commonly forming rhombohedrons with curved to saddle-shaped forms. Twins are common. The colors generally are yellowish-brown to brown and may weather to dark brown or reddish-brown. Varieties containing manganese will show pink, rose and flesh-red colors. The streak is white. The luster is glassy to pearly. *Ankerite* has a subconchoidal fracture and is brittle. The hardness is 3.5 and the Sp.G. 3.02 or more, increasing as the percentage of iron increases. When heated, *ankerite* and ferroan *dolomite* darken and become magnetic. *Ankerite* may easily be mistaken for *calcite*, *dolomite* or *siderite*.

Ankerite has been reported to occur in mineralized vugs in the septarian concretions of the coal strip mines around Oskaloosa and Knoxville (plate 1B). However, Mc Cormick and Bailey (1973) indicate that the brown mineral in the septarian concretions of the Knoxville-Oskaloosa area is wholly *calcite*. They do not recognize *ankerite*.

The Warsaw Formation geodes of the Keokuk vicinity apparently have small crystals of orange-brown *ankerite* or ferroan *dolomite* (plate 4C). *Ankerite* also has been reported in the Upper Mississippi Valley zinc-lead district in vugs in the upper part of the Galena Formation in association with *sphalerite* and *marcasite*.

This mineral is not important commercially and does not occur on a rock-forming scale.

ARAGONITE (calcium carbonate CaCO₃)

Aragonite has the same chemical composition as *calcite*, but crystallizes in the orthorhombic system. Its crystals generally occur as twins that are in short to long

prisms. A pseudo-hexagonal symmetry may be prominent. It also occurs in columnar aggregates and laminated fibrous crusts, and in various other shapes such as globules, stalactites, flower-like forms with curved branching growths called *flos-ferri*, and as the pearly lining in the interior of shellfish. The cleavage is not distinct as in *calcite*. The mineral is brittle with a subconchoidal fracture. It may be colorless, white, gray, yellow, pale green, violet or rose red. The streak is uncolored. The luster is glassy. *Aragonite* is transparent to translucent. Like *calcite*, it fizzes freely in hydrochloric acid. It is slightly harder and heavier than *calcite*. The hardness is 3.5 to 4 and the Sp.G. 2.9.

This mineral is difficult to find and identify in Iowa and it probably is not abundant because it slowly alters to *calcite* when the temperature and pressure conditions change. It has been found with a fibrous *satin spar* structure on the roofs and walls of caves about five miles south of Dubuque in secs. 16 and 17, T. 88N., R. 3E. This variety is called *cave onyx*. The geodes of the Warsaw Formation in southeastern Iowa reportedly contain white crusts and small fibers of *aragonite*. Small quantities of *aragonite* may also be present in the Fort Dodge *gypsum* deposits, but most of this probably has been altered to *calcite*.

The iridescent inner layer of mussel shells called *mother-of-pearl*, found in the Mississippi River and other Iowa streams, is composed of *aragonite* secreted by the mollusks (plate 1C). Pearls, abnormal growths in the interior of the mussels, also are composed of *aragonite*. Because of their organic origin, pearls are not considered to be a mineral in the true sense, although they are used as gems. Many freshwater pearls fully as valuable as those brought up by oriental divers have been found in Iowa shell banks. Colors vary from white, gold, opalescent green, pink, red and black, depending on the food available to the mussels and the mineral composition of the water.

BARITE (barium sulfate BaSO₄)

The most distinctive property of *barite* is its heaviness, for which it is called *heavy spar*. It is characterized by large, flat crystals that are found singly or in groups. It also occurs in globular, fibrous, laminated, granular, needle-like and earthy forms. Cleavage is distinct in two directions and imperfect in another. The mineral is brittle and fractures unevenly. Crystallization is orthorhombic. Crystals may be colorless and transparent, but commonly are white and shades of yellow, brown, pink, red, or blue because of impurities. The streak is white. The luster is glassy and pearly. This mineral closely resembles *calcite*, *selenite*, and *celestite*,



A. Pseudomorphs of *anglesite* after *galena*. Allamakee County. X 1.5



B. Dark-brown "*ankerite*" or ferroan *dolomite* and white *calcite* crystals on light brown *calcite*. From a septarian nodule in the coal strip mines near Pershing. Scale in inches.

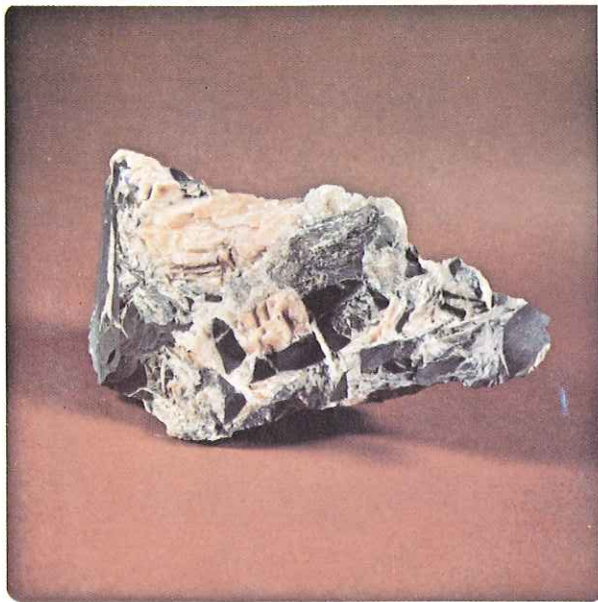
C. *Aragonite* in shells. Specimen on right is from Mississippi River shell beds at Muscatine. Holes are pearl button borings. Compare abalone fragment from California.



D. White to colorless, columnar *barite* crystals set in light and dark brown, flower-shaped *calcite* in black limestone. Strip mines south of Oskaloosa.



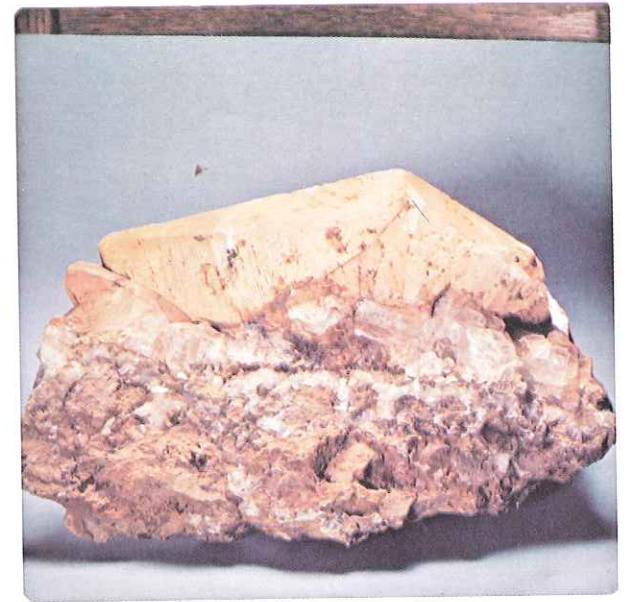
PLATE 2



A. Pink and white *barite* and white *calcite* in black limestone from strip mines east of Bussey. X 0.35



B. Phantom of scalenohedral *calcite* in rhombohedral *calcite*. Galena Formation, Dubuque area. X 0.25



C. Scalenohedral *calcite* twin from Galena Formation near Dubuque. X 0.25

D. Mexican onyx *calcite* found in the Galena Formation near Dubuque.



E. Typical *calcite* rhombs found in Iowa carbonate rocks.



being transparent to translucent and varicolored. However, *barite* will not fizz in hydrochloric acid and is much heavier than *calcite*. *Barite* also is harder than *selenite* and twice as heavy. When powdered and heated on a clean platinum wire, *barite* has a green flame color, while *celestite* has a bright red or crimson flame color. *Barite* has a hardness of 2.5 to 3.5 and a Sp.G. of 4.3 to 4.6.

Although *barite* is a fairly common mineral in Iowa, the deposits generally are sparse and widespread. It has been found in several places in the Dubuque area at the base of the Maquoketa Shale and in the top of the Galena Dolomite in transparent crystals that are faintly yellow and blue and as much as 4 inches long. One collecting location the author visited was on the south side of Highway 20 just behind the Plaza 20 shopping center in the NW¼ SW¼ sec. 26, T. 89N., R. 2E., Dubuque County.

A flesh to pink-colored barite associated with major *calcite* and minor *pyrite* occurs in large veins and vugs in black limestones and septarian concretions of Pennsylvanian age in the Star Coal Company strip mines 5-6 miles east of Bussey on the north side of the road in the SE¼ sec. 14, T. 74N., R. 17W., Mahaska County (plate 2A). A white, fibrous, reticulated *barite* was also seen at this locality. The Weldon Coal Company mine just west of the road going to the Red Rock Dam in the NE¼ SE¼ sec. 34, T. 76N., R. 19W., Marion County, yielded a pink and white *barite* from septaria of gray limestone, as well as from veins in black limestones. Here also, *calcite* is the principal associated mineral. A black limestone in the Lost Creek Coal Company strip mine No. 1 about 3½ miles south of Oskaloosa along Highway 137 yielded a white to colorless columnar *barite* set in brown flower-shaped *calcite* crystals (plate 1D). Elsewhere in the coal strip mines of Marion and Mahaska Counties septarian concretions have yielded excellent specimens of colorless, white and pink, coarsely laminated and crested *barite* on *calcite* and *pyrite*. Some lovely specimens reportedly have been found in the strip mines in the vicinity of Eddyville. The Pershing mines and Wilcox Wildlife Preserve in southeastern Marion County are especially prolific collecting grounds. Occasionally small quantities of *barite* can be found in the outer periphery of coal balls from the strip mines of this area.

The Devonian-age quarry at Coralville in Johnson County has yielded small quantities of white, bladed *barite* with *millerite*. White *barite* also has been collected with *calcite*, *pyrite* and *sphalerite* in the Mississippian-age quarry south of Interstate 80 in the SW¼ sec. 16, T. 79N., R. 17W., Jasper County. Some small *barite* nodules reportedly have been observed in limestone at various scattered locations in the Missouri Series in Decatur County in southern Iowa. Clear,

transparent blue and yellow tabular *barite* crystals also are reported to occur in the Warsaw Shale geodes in a few localities along the Mississippi River in southeastern Iowa. Pint's Quarry near Raymond yields good specimens of white, bladed and crested *barite*, the surfaces of which may be dusted with tiny *pyrite* grains.

Iowa has no commercial *barite* deposits. The leading producing states are Missouri, Arkansas, Georgia, Nevada and Tennessee. The largest use of *barite* is to give weight to drilling fluids used by the rotary well-drilling industry. It is also used in glassmaking; as a white pigment in paints; as an industrial filler and weighing agent, principally in the paint and rubber industries; in barium chemical compounds; in cosmetics; in ceramics; in medicine; in concrete aggregate for weight and for many other industrial processes.

CALCITE (calcium carbonate CaCO₃)

Calcite probably exhibits a greater variety of forms and shapes than any other mineral, although six-sided rhombohedral crystals with perfect cleavage in three directions are very common (plate 2E). Double six-sided pyramid crystals called scalenohedrons also are common. Crystallization is hexagonal. When pure this mineral is colorless or white and transparent, and has a glassy luster, but impurities often add various shades of color, even black, making it opaque. *Calcite* will bubble vigorously in dilute hydrochloric acid. Thin transparent crystals are doubly refracting, that is, when you look through them you will see two images. The hardness is 3 on cleavage faces. The Sp.G. is 2.7.

Calcite is abundant in Iowa as coarse cleavage masses that fill cracks and crevices in limestone and dolomite strata and as crystals partly or completely filling small cavities formerly occupied by fossils such as corals, brachiopods, stromatoporoids, crinoids and cystoids. The limestones and dolomites themselves consist mostly of tiny *calcite* crystals. These may be seen with the aid of a hand lens, especially in the more coarsely crystalline varieties. Very pure limestones consist of 95 percent or more calcium carbonate.

Large rhombohedral masses of *calcite* can be found rather easily at many quarries and exposures in the Cedar Valley and Wapsipinicon limestones in eastern and northeastern Iowa. Two especially good locations worth visiting for this type of *calcite* are the quarry northwest of Central City in the SE¼ sec. 28, T. 86N., R. 6W., Linn County, opened in the Wapsipinicon Formation, and a new quarry about 1½ miles north of Cresco in the NW¼ sec. 12, T. 99N., R. 11W., Howard County, in

the Solon Member of the Cedar Valley Formation. The Central City *calcite* is a unique brownish-gray color.

Clusters of pointed scalenohedron crystals called *dog-tooth spar* can be found lining the sides of vugs and cavities in limestones and dolomites in many quarries and natural outcroppings. Excellent specimens have been collected from quarries in the Cedar Valley-Wapsipinicon sequence in Johnson and Scott Counties and in the Meramec and Osage Series in Van Buren, Washington, Keokuk, Mahaska and Poweshiek Counties and the surrounding areas. Pint's quarry east of Raymond also has good specimens. A quarry opened in the Galena Dolomite along the Mississippi River south of Dubuque has scalenohedron *calcite* crystals measuring up to six inches long, the largest the author has seen anywhere in Iowa. Twin crystals measuring up to ten inches long have been found here (plate 2C). This quarry also has the clear transparent variety of *calcite* called *Iceland spar*, showing the characteristic double refraction, and "phantom" *calcite* outlined by *pyrite* (plate 2B).

A rare "phantom" *calcite* containing a purplish amethyst-like shading and much finely disseminated *pyrite* in the interior occurs in a quarry 3½ miles north and one mile west of New Sharon, in the SW¼ NE¼ sec. 25, T. 78N., R. 16W., Poweshiek County. The purplish cast may be due to an organic coating on crystal faces in the interior or to oxidation of included iron or manganese. When the *calcite* is turned in the sunlight the minute *pyrite* inclusions glisten like gold. The *calcite* is found in scalenohedral crystals and rhombohedral masses in vugs in a brown dolomite rock belonging to the lower St. Louis or Spergen Formation in the bottom of the quarry. Another "phantom" *calcite* wholly outlined by *pyrite* grains also is present in this quarry. Tiny clusters of white to yellowish-gray, bladed *barite* and much botryoidal *chalcedony* may be found around the base of some of these *calcite* crystals. A few cleavage masses of dark *sphalerite* were seen on the *calcite*. A very minor amount of capillary *millerite* piercing *calcite* also was found here.

Small *calcite* geodes have been collected from the Rapid Member of the Cedar Valley Formation in a roadcut 2½ miles north of Waverly in the NW¼ NE¼ sec. 22, T. 92N., R. 14W., Bremer County. A quarry about three miles north of Littleton along the Little Wapsipinicon River in the SE¼ SE¼ SW¼ sec. 28, T. 90N., R. 10W., Buchanan County yields small to large slightly flattened *calcite* geodes. Other quarries near West Union in Fayette County and Spillville in Winneshiek County yield good *calcite* geodes. The Shell Rock - Cedar Valley sequence exposed in quarries and natural outcroppings along the Shell Rock River valley in northeastern

Cerro Gordo County and northwestern Floyd County yield small to medium sized *calcite*-lined vugs that are replacements of fossils. The Warsaw Shale geodes of southeastern Iowa contain large "barrel" *calcite* crystals on quartz. Rarely these geodes are completely lined with *calcite*.

Travertine, or calcareous tufa, a deposit of massive, porous *calcite* formed by evaporation of calcareous spring water or river water is abundant at many limestone exposures in eastern Iowa. It commonly occurs as white or yellow spongy-looking coatings on limestone surfaces along streams. Travertine also may be found in caves as stalactites, icicle-like dripstone deposits hanging from the ceiling, and as stalagmites, inverted cones or accumulations built up on the cave floor. Spectacular Cold Water Cave in Winneshiek County has travertine dripstone and flowstone deposits of unusual development and beauty. A compact, banded *calcite* deposit called *Mexican onyx*, which probably is a flowstone deposit, can be seen on the Galena Dolomite at the YMCA Camp in Union Park Hollow just north of Dubuque in the NE¼ SW¼ sec. 10, T. 89N., R. 2E., Dubuque County. The bands are irregular and wavy with a white to yellowish-gray and brown color (plate 2D). Similar deposits were seen in the roadcut along the Great River Road leading into North Buena Vista in Clayton County.

Many mineral collectors eagerly look for large calcareous septarian concretions in the coal strip mines of Marion, Mahaska and Monroe Counties which yield beautiful crystallized minerals from the intersecting veins, cracks and vugs. The septaria usually are spherical and range from several inches up to several feet in diameter (plates 3A and 6C). Generally, weathered septaria are light gray with the intersecting veins of the more resistant *calcite* left standing in relief. Rarely, septaria have been found with all the limestone or calcareous claystone matrix dissolved, leaving a frame of "box *calcite*" veins. Unweathered septaria commonly have a matrix of gray or black limestone. The intersecting veins may be completely filled with minerals while others may be only partially filled and lined with crystals. Brown, coarsely crystallized *calcite* is the principal mineral filling the septaria veins (plates 1B, 3A and 4A). This mineral has been variously misrepresented as *siderite*, ferroan *dolomite*, *ankerite* and *sphalerite*. The brown color is attributed to very small percentages of iron and manganese impurities. A completely filled vein usually has a comb-like appearance in cross section and may be color-banded parallel to the walls of the vein (plate 3A). Where veins are not completely filled the brown *calcite* usually terminates in small merged rhombohedral crystals. This brown *calcite* also is found filling cracks in black bedded limestones in the strip mines. Frequently the brown crystals have an oxidation film or coating on the surface that is beautifully iridescent in gold, orange, red, purple, blue and green.



A. Yellow and brown *calcite* filling veins of septaria fragments that have been sawed to show internal structure. Scale in inches.



B. Polished fragment of *Hexagonaria* fossil coral. Scale in inches.

C. Mass of blue-gray crystalline *celestite* from the gypsum mine near Sperry.



D. Flattened claystone concretion with *celestite*, *calcite* and *marcasite* inside. Fort Dodge area.



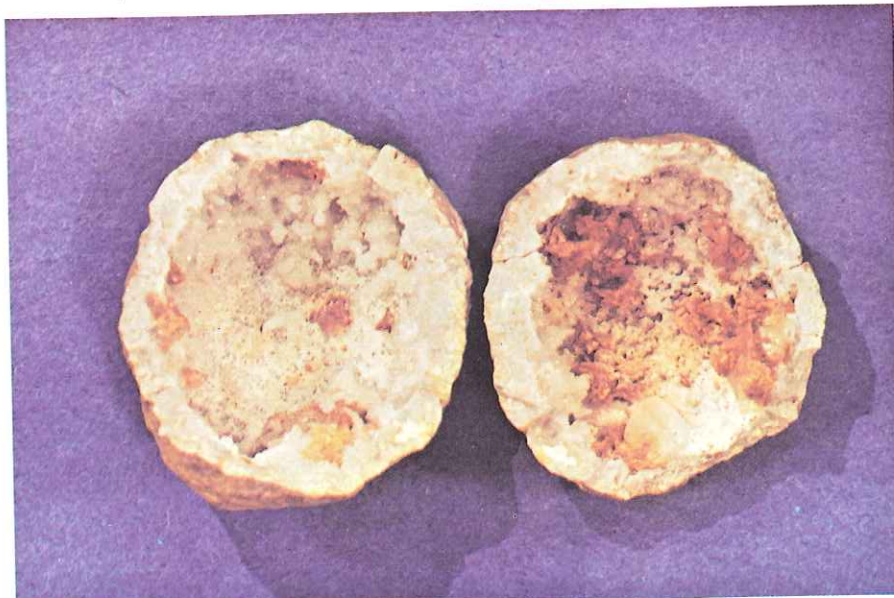


A. White *calcite* crystals on brown *calcite* from vugs in dark limestones of the strip mines near Oskaloosa. X 0.25



B. Yellow *dolomite* crystals intergrown with crystalline *quartz* and milky or gray *chalcedony*. From the upper part of the Keokuk Formation north of Keokuk. Scale in inches.

C. Geode containing brown *dolomite* crystals with *quartz*, *calcite* and *kaolin*. Lee County. X 1.0



D. Mineralized vug from Pint's quarry showing clear *calcite*, brown *fluorite* and *pyrite* X 1.1.



The brown crystals exhibit an unusual curvature and have led some to suggest the material has been partially altered by dolomitization. McCormick and Bailey (1973) conclude the curvature is due to interference of one crystal with another during growth and distortions of the crystal lattice caused by formation of iron-oxide and manganese-oxide particles along the growth lines. A colorless to milky white and gray *calcite* occurs in flower-like aggregates or "pineapples" and as individual small, sharp scalenohedron crystals in most of the septaria of this area (plate 4A). These usually are found growing on the brown coarsely crystallized *calcite*.

A fibrous variety of *calcite* having a silky luster and called *satin spar* has been collected from the Ste. Genevieve Limestone (Pella beds) about 2½ miles due south of Pella in Marion County. Fibrous *gypsum* also is called *satin spar* but is much softer and does not bubble in acid like *calcite*.

The skeletal remains of many fossils including forams, sponges, stromatoporoids, corals, bryozoans and echinoderms are composed entirely of *calcite*. Lapidarists like to cut and polish slabs of the colonial fossil coral *Hexagonaria*, (plate 3B). This is the coral of the well-known "Petoskey stones" of northern Michigan. It is widespread in the Cedar Valley Formation along the Iowa and Cedar River valleys and in quarries in Black Hawk, Buchanan, Benton, Cedar and Johnson Counties. Specific collecting locations for *Hexagonaria*, cited by J.R. Rose in her book "Fossils and Rocks of Eastern Iowa", are the quarry just east of Independence; the Nichols quarry north of Vinton; the Curtis Bridge and Mid-River quarries off Highway 218 in northern Johnson County; and the Atalissa quarry in south-central Cedar County. Any of the exposures and quarries in the Cedar Valley Formation in east-central Iowa are likely collecting sites. Smaller fragments of *Hexagonaria* may be found in gravel pits. Very good specimens of *Hexagonaria* may be observed among the boulders supporting the memorial plaque of Lincoln's Gettysburg Address on the front lawn of the Johnson County Courthouse in Iowa City.

Another type of *calcite* is *cone-in-cone*. It consists of a succession of small cone-shaped structures one within another in inverted positions. It usually is found in shales or marls, but may be found in clay ironstones or coal. One of the favorite cone-in-cone *calcite* collecting sites in Iowa is near Bells Mill Park about five miles north of Stratford where County Road E crosses the Boone River in the SE¼ SW¼ sec. 16, T. 87N., R. 26W., Hamilton County (plate 6B). The cone-in-cone here, which is black, is found on the west side of the river across from the park and just south of the bridge in a layer up to a foot thick. Other localities for cone-in-cone *calcite* are on the Brossart farm one mile east of Fairport in the NW¼ sec. 30,

T. 77N., R. 1E., Muscatine County, and in the bed of Swede Hollow, sec. 10, T. 72N., R. 22W., Lucas County (plate 6A).

Loess-kindchen are rounded and irregular nodules of calcium carbonate, generally grayish-orange or tan in color, found on the surface of the loess deposits in the counties bordering the Missouri and Big Sioux Rivers. Individual specimens may range up to the size of a grapefruit or larger.

Petrified wood with the internal structure consisting largely of tan and dark brown to black calcium and magnesium carbonate and yellowish to black iron sulfide can be found in operating and abandoned coal strip mines east and southeast of Knoxville and in the Pershing, Bussey, Oskaloosa and Lovilia areas of Marion, Mahaska and Monroe Counties (plates 5B, 5C, 5D). The original wood tissue was completely infiltrated by *calcite* and *marcasite* or *pyrite*. When cut and polished across the grain this petrified wood takes a high gloss finish much like a black marble, with the woody pattern in tan. The iron sulfides have a duller to submetallic finish and generally are most abundant around the periphery of the logs. Irregular veins of white secondary *calcite* add to the beauty of this material. Its amazing how well the wood structure is preserved in these specimens considering they are obtained from strata of Pennsylvanian age and are about 250 million years old. This wood is mainly of the gymnospermous tree *Cordaites*. Amateur collectors often mistakenly call it *Lepidodendron*. Several large *Cordaites* logs can be observed on the Lee Deeringer property southeast of Knoxville in the NW¼ Sec. 33, T. 75N., R. 19W., Marion County.

Lepidodendron generally is found as impressions of the bark in siltstones or fine sandstones which preserve the external features of the plant, but not the internal structure (plate 5A). This is not petrified wood. Good *Lepidodendron* specimens have been collected around Pella, Winterset and Muscatine. The bulk of the tree's diameter was formed of layers of bark surrounding a small core of wood that seldom attained a diameter of more than six inches. This wood core can be found as a calcium carbonate petrification, but the small size explains why petrified *Lepidodendron* is found so infrequently. On the other hand, the wood of the *Cordaites* trees grew to a large diameter and petrified specimens are much easier to find.

The University of Iowa has assembled an outstanding collection of petrified wood and fossilized impressions and compressions of wood from Iowa. An excellent exhibit can be seen on the third floor of the Chemistry-Botany Building in Iowa City.

Coal balls also contain fossil plant fragments in a matrix of calcium carbonate and iron sulfides. The plant material in coal balls often is remarkably well preserved, in its original organic condition (plates 11B and 15B). However, *calcite* or *pyrite* has infiltrated the plant tissues to cause petrification. Localities for finding coal balls in Iowa are listed under the discussions of the minerals *pyrite* and *marcasite*.

Calcite in the form of limestone ranks first in economic importance among Iowa minerals as a road-building material. Limestone is the principal raw material used in manufacturing cement. Annually Iowa uses more than 26 million tons of limestone for concrete aggregate and roadstone, cement manufacture and agricultural lime. There are five cement plants in Iowa that produce more than 14 million barrels of cement each year. The value of this product, close to 50 million dollars per year, makes cement manufacturing our leading mineral industry.

There are literally thousands of other uses of *calcite* in the form of limestone. It is used in fertilizers, fluxes, building and ornamental stone, as rip rap on dams, as a supplement for stock foods and in the manufacture of quicklime and hydrated lime. Quicklime and hydrated lime have hundreds of chemical and industrial uses in steelmaking, in sugar refining, in water treatment, in manufacture of chemicals, paper, glass, bleaching powders, insecticides, in soil stabilization, and plasters and mortars.

CELESTITE (Strontium sulfate SrSO₄)

Celestite is a soft, heavy, glassy mineral resembling *barite*. The crystals are orthorhombic and commonly flattened or prismatic. It occurs in fibrous veins and massive and granular forms, but usually it is in crystals. It is colorless to white and faint blue or gray, but may be reddish. It is transparent to translucent. The luster is strongly glassy and sometimes pearly. The streak is white. *Celestite* has two good cleavages, basal and prismatic, and another poorer one, the side pinacoid. It is commonly striated parallel to the basal cleavage. *Celestite* is brittle and fractures unevenly. It has a hardness of 3 to 3.5 and a Sp.G. of 3.97 when pure. This mineral generally is found in sedimentary deposits including limestone, dolomite, shale, marl, sandstone, gypsum, anhydrite and rock salt.

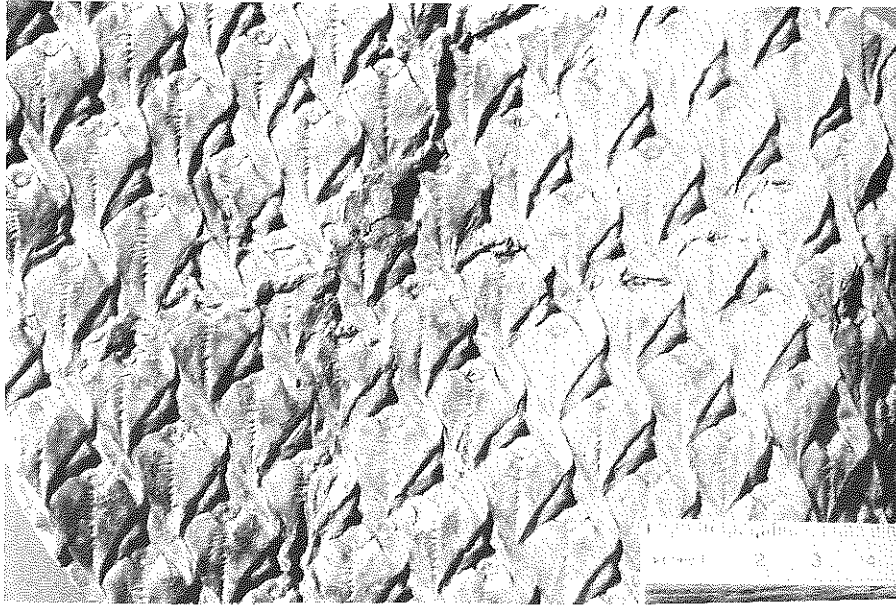
There are three known occurrences of *celestite* in Iowa, one being inaccessible and another occurring in a deep mine. All are associated with gypsum deposits. The first observed occurrence was more than a century ago near Fort Dodge by State Geologist Charles A. White.

Approximately 100 years after White's original discovery, small quantities of *celestite* are again being found in the Fort Dodge area largely through the aggressive curiosity of amateur collectors. One exposure occurs along the north side of the road about a quarter of a mile east and downhill from the Johnston Clay Company plant near the center/south line SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 8, T. 88N., R. 28W., Webster County. The *celestite* is found as small, translucent blue-gray crystals occupying the interior of dark, flattened, calcareous claystone concretions that are as much as 8-10 inches long (plate 3D). The concretions are set in black fissile shales of Pennsylvanian age. *Calcite*, *barite* and iridescent *marcasite* are associated with the *celestite*. *Calcite* probably is the major mineral in these concretions.

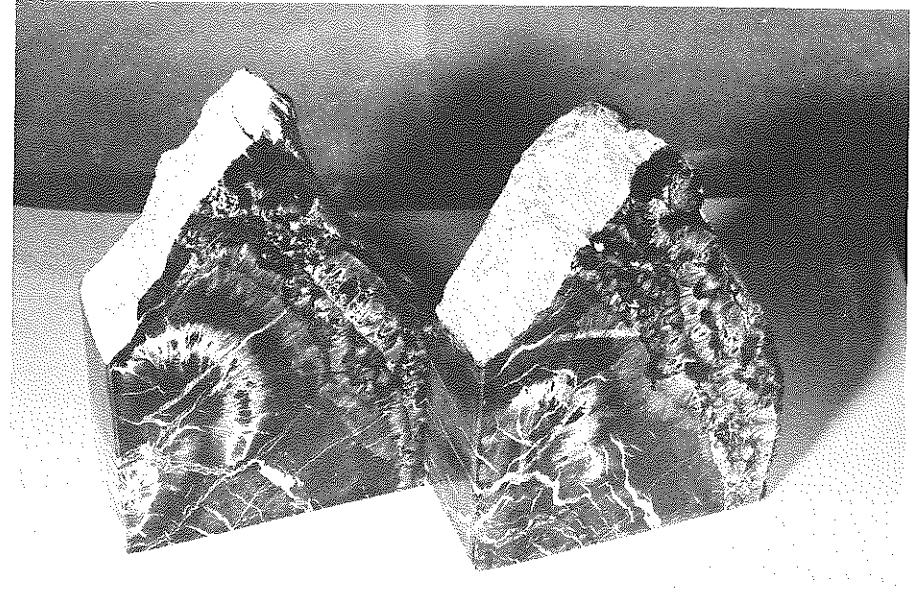
The other two known occurrences are in the U.S. Gypsum Company mine at their plant near Sperry in Des Moines County at a depth of about 600 feet, and in an exploratory core drilled just north of Centerville in sec. 24, T. 69N., R. 18W., Appanoose County at about 426 feet. The Sperry deposits occur in the Spring Grove Member of the Wapsipinicon Formation of Devonian age, while the Centerville occurrence is in the St. Louis Formation of Mississippian age. Both are thin and lenticular bodies associated with brown dolomite rock and immediately overlying beds of massive white *gypsum*. The crystals are mostly imperfect and tabular and clear to white, gray, and pale blue at Sperry (plate 3C). They are smaller and prismatic in the Centerville core.

These deeply buried *celestite* finds indicate that the mineral may be scattered rather widely in the Mississippian and Devonian strata associated with the Iowa *gypsum* deposits. Additional discoveries probably will occur in the future as new mines are opened. There are no indications that the mineral will be found in commercial quantities however.

Celestite (SrSO₄) and *strontianite* (SrCO₃) are the principal sources of strontium which is consumed mainly in the form of compounds to manufacture fireworks and related products such as signal flares, tracer bullets and fusees. When burned, strontium colors the flame a brilliant crimson red. The next time you see a fireworks display, remember the red rockets, parachute flares and Roman candles are made from blue *celestite*! Other uses of strontium compounds are as glazes in ceramics, in medicine, and in beet-sugar refining. The principal strontium mineral deposits in the United States are in Texas, California, Arizona and Washington. The best collecting locations appear to be in Ohio, Texas and California.



A. *Lepidodendron* bark impression in siltstone from Pennsylvanian-age Des Moines Series near Knoxville. Metric scale.

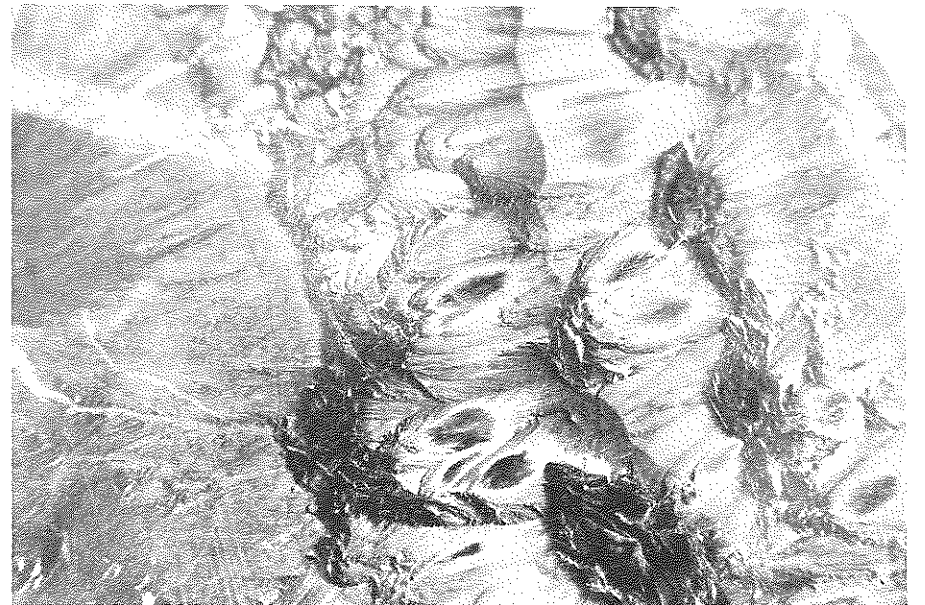


B. Bookends made from *Cordaites* petrified wood and given to the author by one of his rockhound friends.

C. Small log of *Cordaites* petrified wood that is principally *calcite* with iron sulfide around the periphery. Thin slab is polished to natural gloss. X 0.20

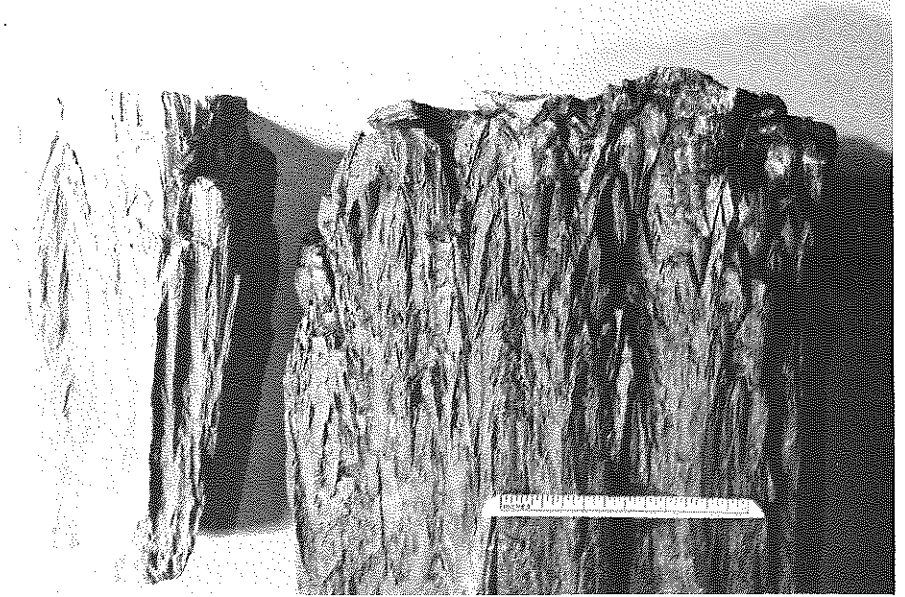


D. Close-up of polished *Cordaites* wood. X 3.0.



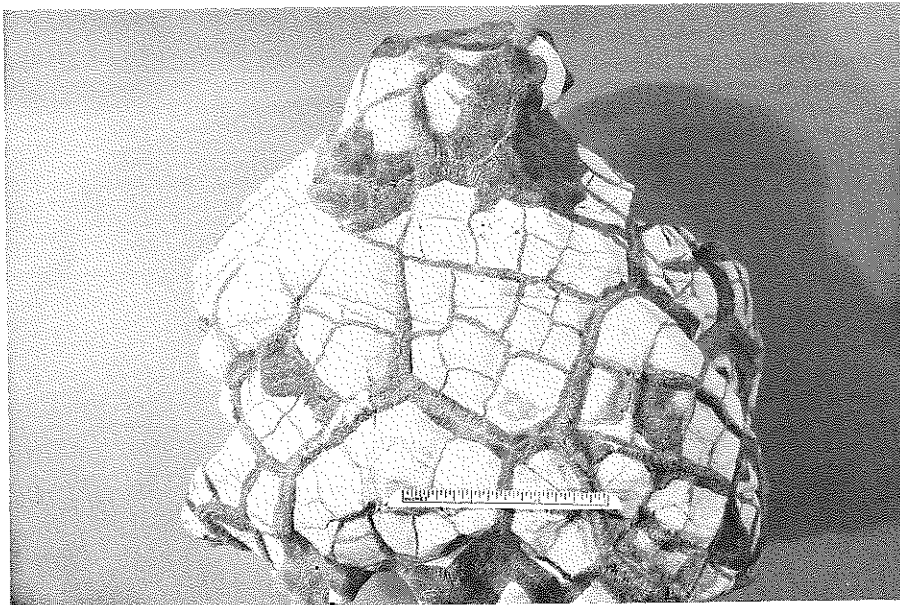


A. *Calcite* cone-in-cone structures. Those on left and in center are from the Des Moines Series of Lucas County. Specimen on right was found east of Fairport, Muscatine County.

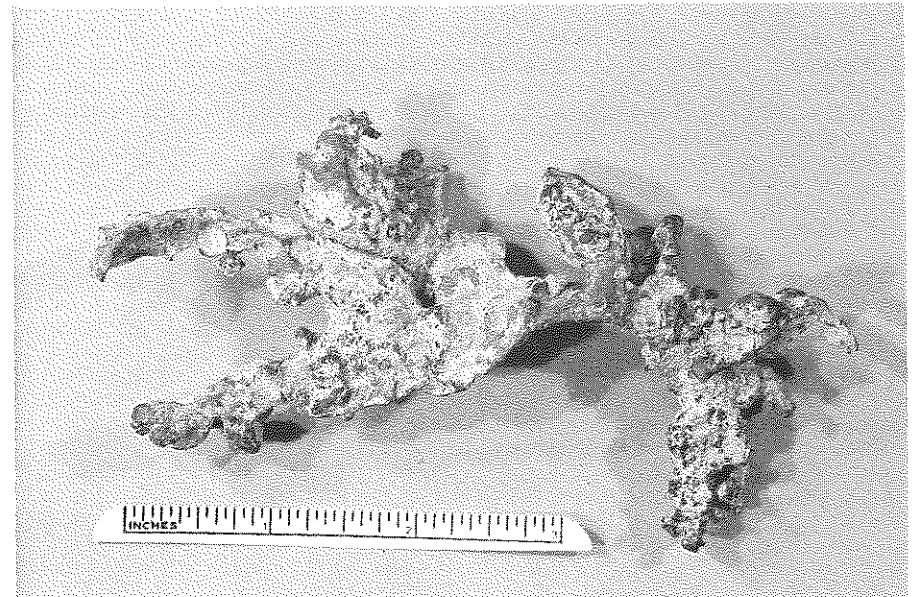


B. *Calcite* cone-in-cone structures. Specimen on left is from near Fort Dodge. Large dark specimen on right is from Bells Mill Park exposure north of Stratford in Hamilton County.

C. Septarian concretion with openings completely filled with brown *calcite*. Found in old gravel pit near Schaller and given to the Iowa Geological Survey.



D. Native *copper* from the mineral cabinet of the Iowa Geological Survey.



CERUSSITE (lead carbonate $PbCO_3$)

Because it is light in color this mineral is known as white lead ore. Small crystals commonly are flat and platy. Larger, pyramid-shaped twinned crystals may form skeletal lattice-like intergrowths. The crystals are orthorhombic. More often the mineral occurs in granular compact masses or as white porcelain-like crusty coatings on weathered *galena*. *Cerussite* generally is colorless, white or gray, but may be yellow and brown owing to impurities. The streak is white. The luster is glassy, greasy or pearly. *Cerussite* fizzes and dissolves in dilute nitric acid, but not in hydrochloric acid. It may show slight reaction in warm hydrochloric acid. The mineral has a hardness of 3 to 3.5. It is very heavy for a non-metallic mineral, having a Sp.G. of 6.4 to 6.6, one of its most distinguishing properties.

In Iowa *cerussite* is fairly difficult to find. It occurs as a white to blue-gray coating or thin scale on *galena* in the oxidized zone above the water table in the old zinc-lead mines around Dubuque, and as small glassy crystals in cavities in the *galena* or as granular crusts on the *galena*. It also can be found in cavities in the lead ore from the old Lansing lead mines on the Ed Walleser farm in northeastern Allamakee County in the NE¼ NW¼ sec. 10, T. 99N., R. 4W., and from the old Mineral Creek mines on the Clem Brynes farm in the northwestern part of the county in the NW¼ SE¼ sec. 13, T. 99N., R. 6W. The source rock in the Allamakee mines is the Oneota Dolomite, the lower member of the Prairie du Chien Formation. Excellent quality *galena* has been found in all the valleys cut in the Oneota Dolomite in this area, but only as small pockets and fissures that are so scattered and limited they have never returned to the miners the expense of prospecting for it. The ore-bearing crevices usually have considerable clay adjacent to the wall rock. The most profitable collecting for amateurs in these areas will be to pick over the dumps around the old mine shafts and immediately downslope from the dumps looking for lead fragments with white coatings and glassy crystals of *cerussite* on the *galena*. Usually the best collecting is done after a heavy rain in the spring before grass, weeds and brush have covered the ground. *Cerussite* is always of secondary origin and occurs in the upper oxidized zone of ore bodies. It is formed by weathering of *galena* through the action of carbonated waters. It is commonly associated with *anglesite* which it resembles, and *limonite*.

In summary, when looking for *cerussite* and *anglesite*, look for *galena* first, then examine the lead ore closely for associated lead carbonate and lead sulfate.

Cerussite is an important ore of lead in Missouri, Colorado, Arizona, Utah,

Idaho and New Mexico. Formerly it was a minor ore in the Upper Mississippi Valley district.

CLAY MINERALS (hydrous aluminum silicates)

Clay is a soft earthy rock, mire or mud made up of fine mineral particles about the size of dust. The minerals are so tiny they cannot be identified with the unaided eye. However, as these minerals are extremely widespread in soils and sedimentary rocks in Iowa, they form an important part of the geology. There are several groups of clay minerals. The principal divisions are the *kaolinite*, *halloysite*, *montmorillonite*, *illite*, *chlorite* and *vermiculite* groups. They differ in crystal structure and physical properties, but are all finely crystalline. Chemically, they are hydrous aluminum silicates containing calcium, sodium, potassium and other ions. Impurities such as *quartz*, *calcite*, *feldspar*, *pyrite* and organic material usually are mixed with the true clay minerals.

All clays are formed from the weathering or alterations of other rocks and minerals, mainly aluminum silicates such as the feldspars, micas, certain pyroxenes, amphiboles, garnets, etc. Clay may be found where it was formed or it may have been carried long distances by wind or water before being deposited. The distinctive property of clay is that it forms a pasty moldable mass when wet and when dry becomes firm as a rock. It often has a soapy feel and may be known locally as soapstone. It also has an earthy odor. Clay has many colors including white, gray, black, green, red, and yellow, depending on the impurities present.

The principal clay and shale (a hardened and laminated form of clay) formations in Iowa are the unconsolidated glacial drift clays; shales of Cretaceous age such as exposed in the river bluffs north of Sioux City and underlying much of northwestern Iowa; shales of Pennsylvanian age widespread in the southern part of the state; the Maple Mill, Sheffield, and Lime Creek shales of Devonian age in the southeastern and north-central counties; and the Maquoketa Shale of Ordovician age in the northeastern counties. Scattered pockets of clay may occur in solution cavities in limestone and dolomite strata. A snow-white to brown crystalline powder of *kaolinite* clay has been found in southeastern Iowa geodes. This may be found in pockets in the chalcedony shells or in the geode cavity. Some geode cavities reportedly are completely filled with *kaolinite*.

Few systematic studies have been made of the composition of Iowa clays. According to Dr. John Lemish of the Iowa State University Earth Science

Department, the limited information available indicates that the main mineral in Iowa clay-shales is *illite*, with *chlorite*, *montmorillonite* and varying amounts of *quartz*. *Kaolin* mixed with *chlorite*, *illite* and considerable non-clay material characterizes the glacial clays. Dr. George McCormick of the University of Iowa Geology Department indicates compositions of about 50 percent *kaolin* and 50 percent *illite* for the Pennsylvanian clays of south-central Iowa. Some *montmorillonite* and minor *chlorite* are present, and of course, *quartz*.

Because clay is widespread, can be molded easily and heated to make brick and ceramic-ware, it was one of the first earth materials used by man. Other uses for clay are in manufacturing drain tile and sewer pipe, as a cement mix, as paint filler, as a refractory called fire brick, in lightweight concrete aggregate, in bleaching materials, as absorbents, and in drilling mud. Most Iowa clays are used in the manufacture of heavy clay products. A small amount of fire clay is produced. The main plants are located around Mason City, Sheffield, Rockford, Adel, Des Moines, Redfield, Sergeant Bluff and Lehigh. A lightweight aggregate plant and shale pit was opened near Centerville in 1960 and is now one of the largest producers of clay products in Iowa.

COPPER MINERALS

Traces of several copper-bearing minerals—*chalcopyrite*, *chalcocite*, *malachite* and *azurite*—have been reported in the zinc-lead ores of the Upper Mississippi Valley district (figure 1). *Chalcopyrite* is one of the original minerals deposited during the ore-forming episode of this district (others are *quartz*, *dolomite*, *sphalerite*, *marcasite*, *pyrite*, *galena*, *barite* and *calcite*). *Chalcopyrite* seems to be extremely scarce in the Dubuque area, although it has been reported at some of the old mine dumps around Dubuque. The location of numerous old pits and mine workings are shown on the U.S. Geological Survey Mineral Investigations Field Studies Maps. For mineral collectors working this area, these maps with the accompanying text will be very useful, even though many of these old pits are now filled or overgrown. *Chalcocite*, *malachite* and *azurite* probably also are extremely rare in the Dubuque area.

Small crystals of *chalcopyrite* have been found in geodes near Keokuk and Denmark in Lee County, with deep green crusts of *malachite* on some of the crystals. Small crystals of *chalcopyrite* on *calcite* have been collected at Pint's quarry along Highway 20 east of Raymond; small specimens of green *malachite* on *calcite* occur in the septarian concretions from the Wilcox Wildlife Preserve, an old

coal strip mining area mostly in sec. 5, T. 74N., R. 18W., Marion County. Tiny crystals of sphenoidal *chalcopyrite* also have been reported in vugs in the septaria of this area. Short wiry filaments of green *malachite* were observed in septaria of other strip mines in Marion and Monroe Counties. One such location is the Lovilia Coal Company mine about three miles northwest of Lovilia in the NW¼ sec. 8, T. 73N., R. 18W., Monroe County.

Occasionally small nuggets and irregular masses of native copper weighing up to a few pounds are found in the glacial drift or gravel deposits of Iowa (plate 6D). Two of these nuggets are on display at the Iowa State Historical Museum in Des Moines. The Indians of this region also may have brought pieces of native copper from the Lake Superior region to use in making their copper implements and ornaments.

Azurite (basic copper carbonate $\text{Cu}_3(\text{OH})_2(\text{CO}_3)_2$) or blue carbonate of copper, has a characteristic azure or deep blue color. It commonly occurs in short, radiating, tabular crystals that are monoclinic. The luster is glassy. It also may occur as massive or botryoidal aggregates with a dull or earthy luster. The streak is blue. It is transparent to opaque. The hardness is 3.5 and the Sp.G. 3.7 to 3.8. *Azurite* is much rarer than *malachite* with which it may be associated. Both *malachite* and *azurite* are formed by oxidation of *chalcopyrite*.

Chalcocite (cuprous sulfide Cu_2S) or copper glance, is dark lead-gray and tarnishes dull black and sooty. It usually is massive and granular or compact. Orthorhombic crystals are rare. Its streak is dark gray to black and shiny, and the luster is metallic. *Chalcocite* is softer and heavier than *chalcopyrite*. The hardness of *chalcocite* is 2.5 to 3 and the Sp.G. 5.5 to 5.8.

Chalcopyrite (copper iron sulfide CuFeS_2), sometimes called copper pyrite, is a brass-yellow mineral with a greenish-black streak and metallic luster. It often tarnishes to a deep blue or green and may be iridescent. It closely resembles *pyrite*, but is much softer. Crystallization is tetragonal. Although the mineral usually is massive, crystals are common and characteristically sphenoidal, resembling tetrahedrons. The hardness is 3.5 to 4 and its Sp.G. 4.1 to 4.3. *Chalcopyrite* is the most important ore of copper in the sulfide deposits of Arizona, Montana, Utah, Nevada, New Mexico and California.

Malachite (basic copper carbonate $\text{Cu}_2(\text{OH})_2\text{CO}_3$) or green carbonate of copper, is distinguished by its bright emerald color and its reaction in hydrochloric acid.

This mineral commonly is found in botryoidal and stalactitic masses with smooth surfaces and a banded or radial fibrous structure. It also may be incrusting or earthy. Monoclinic crystals are rare. The streak is light green and the luster is dull in earthy varieties, silky in fibrous types, and glassy in crystals. The mineral is translucent to opaque. The hardness is 3.5 to 4 and the Sp.G. 3.9 to 4.

None of the copper minerals are commercially important in Iowa.

DOLomite (carbonate of calcium and magnesium $\text{CaMg}(\text{CO}_3)_2$)

When speaking of dolomite it is necessary to distinguish between dolomite rock and the mineral *dolomite*. The mineral is a calcium-magnesium carbonate with iron commonly substituting for magnesium. It is a common rock-forming mineral and great bodies of rock in the geologic column are called dolomites because they have the composition of the mineral *dolomite*. As a mineral, *dolomite* has a granular, compact or crystalline structure. Hexagonal crystals commonly form rhombohedrons resembling *calcite*, but *dolomite* does not occur in scalenohedrons. Generally the crystals are smaller and far less abundant than *calcite*. Often the crystal faces and crystal aggregates are curved into saddle-shaped forms. Cleavage is perfect in three directions, although it is not as obvious as in *calcite*. Pure *dolomite* is colorless or white, but may be gray or green, becoming yellow and brown when iron is present as an impurity. The luster varies from glassy to pearly. *Dolomite* is transparent to translucent. The streak is white. The hardness is 3.5 to 4 and the Sp.G. 2.8 to 2.9. This mineral bubbles much more slowly in cold dilute hydrochloric acid than *calcite*. If the percentage of iron exceeds the percentage of magnesium, *dolomite* grades into *ankerite*.

Aggregates of small, clear to white, yellow, orange and light brown rhombohedral *dolomite* crystals, exhibiting the characteristic curved surface, occur in the Warsaw Formation geodes and vugs in the Keokuk area of southeastern Iowa. The orange and light-brown specimens probably are ferroan *dolomite* or *ankerite*. *Quartz*, *chalcedony*, and less frequently *calcite*, are the chief associates. The best specimens I have collected are from the lower part of the exposure in the roadcut leading to the Iowa Gateway (barge) Terminal about two miles north of Sandusky along the north line NW¼ NW¼ sec. 30, T. 66N., R. 4W., Lee County (plate 4C). You must get permission here. The canyon-like walls are very dangerous and unsuited for climbing.

The Keokuk Limestone near Keokuk has yielded intergrowths of small *dolomite*

crystals that are a faint yellow and pink and translucent. Some interesting crystal aggregates of white curved *dolomite* associated with black *sphalerite* can be found in the Keswick quarry in Keokuk County and in the Coralville quarry in Johnson County. The septarian concretions from the strip mines in the Pershing area and northwest of Bussey, in the Wilcox Wildlife Preserve, have yielded small clusters of white to gray typically curved, saddle-shaped crystals of *dolomite*. *Dolomite* crystals also have been reported from vugs and crevices in limestones in the Dubuque and Fort Dodge areas. A hand lens will show tiny, sparkling *dolomite* crystals lining the interior of small cavities in almost any dolomite rock in eastern and northeastern Iowa. Massive dolomite formations belonging to the Devonian, Silurian and Ordovician Systems of rock are widespread in this part of the state. The dolomite probably formed by alteration of ordinary limestone that was saturated by sea water or ground water containing magnesium in solution.

The chief uses of dolomite rock in Iowa are for roadstone, concrete aggregate and agricultural lime. A small amount is used as a building stone in architectural panels. The magnesia from dolomite rock is useful for refractories for lining metallurgical furnaces in the iron and steel industries because it will not fuse or melt. Basic magnesium carbonate compounds made from dolomite have numerous uses as an alloy of metals, in chemicals and in insulation materials.

FLUORITE (calcium fluoride CaF_2)

Fluorite, or fluorspar, usually is found in cubic or octahedral crystals that are isometric. Penetration twins of cubes are common. *Fluorite* also is found as cleavable masses and as fine to coarse granules. Cleavage is perfect in four directions, forming octahedrons. Colors are shades of violet, blue, green, yellow, white, brown and pink; it is also colorless. The yellows, greens and violet-blues are most common. *Fluorite* has a white streak and glassy luster. It is transparent to translucent. The mineral is brittle and fracture surfaces are uneven to conchoidal. *Fluorite* has a hardness of 4 and is one of the 10 common minerals used in the Mohs hardness scale. The Sp.G. is 3.18. The mineral resembles *calcite*, but is harder and will not bubble in hydrochloric acid.

Pale-amber to brown and rarely clear *fluorite* associated with *calcite* and *pyrite* occurs in vugs in the Cedar Valley Limestone in Pint's quarry just east of Raymond, in Black Hawk County (plate 4D). The cubic crystals are distinctive. *Fluorite* also has been found at the contact of the Maquoketa and Galena Formations on the river bed at Volga, in Clayton County, in irregular crystal-lined vugs ½ to 4 inches

across. This exposure can be seen only during low-water periods. The Volga *fluorite* consists of color-zoned cubes as large as 5 millimeters on a side. Colors range from clear through yellow to purple. *Calcite*, *pyrite*, and *sphalerite* are associated crystals. They usually are surrounded by phosphatic and dolomitic debris (plate 7A).

Because *fluorite* occurs under such widely varying conditions, it probably will be found in other places in Iowa. It is common as a vein mineral in limestone and dolomite and as a gangue mineral in metallic ores. It has not been found in the Upper Mississippi Valley zinc-lead district, although this does not mean it is not present there.

Fluorite is used as a flux in making steel, in the manufacture of opal glass, in enameling cooking utensils and in the preparation of hydrofluoric acid. Colorless transparent crystals are used for making optical lenses. The main producing states are Illinois, Kentucky, Montana, California, Utah and Nevada. The prospects of finding commercial deposits in Iowa do not appear promising.

GALENA (lead sulfide PbS)

Galena is a soft, heavy, lead-gray mineral that commonly occurs in cubic crystals with excellent cleavage in three directions at right angles (plate 7B). Crystallization is isometric. *Galena* also is found as cleavable masses. Freshly broken surfaces have a shiny metallic luster something like aluminum foil, but may tarnish to dull gray. Both the color and streak are dark lead-gray. The mineral is brittle and has a hardness of 2.5. The Sp.G. is 7.4 to 7.6. *Galena* is insoluble in water.

For a discussion of the early history of lead mining in Iowa and the important role played by Julian Dubuque, the reader is referred to page one of this book. After Dubuque's death in 1810 the Indians destroyed all of his works, smelters, home, etc. and refused to give other white men mining concessions. He was buried on a high bluff at the mouth of Catfish Creek with an elaborate ceremony. One of his smelting furnaces was at the foot of the bluff just below the grave.

Work in the mines was continued sporadically by the Indians. Their methods in taking up the ore were relatively simple, consisting of digging with hoes, shovels, pick axes and crowbars which they obtained from the traders. No shafts were sunk, although short walk-in drifts were dug into the hillsides. Not until after the Black Hawk treaty of 1832 was the land west of the Mississippi legally opened to settlers

and miners who quickly crossed the river to establish the village of Dubuque. From then on lead mining boomed and the population grew rapidly.

Lead sulfide, zinc sulfide and zinc carbonate were the only commercial minerals found in the Dubuque district. Zinc ore never attained the importance of lead ore in Iowa. The lead ore occurred in vein deposits that filled vertical joints called "gash-veins" or "crevices" at different levels in the magnesian limestone bedrock (Galena Formation) of this area. Some of these veins were traceable for more than a mile. Much residual lead or "float" was found under the thin soils of the hillsides and alluvial soils of the stream valleys in the early years. The float deposits were formed by weathering of the carbonate rock around the sulfide veins, leaving concentrations of *galena* on the bedrock surface that were later covered by soil and alluvial materials. Lead production reached a peak between 1844 and 1849. In 1852 the Upper Mississippi Valley mines produced about 87 percent of the total United States output. Production gradually declined after 1857, but the district was a main source of lead in the country until near the end of the century. The last of the Iowa lead mines shut down about 1917. A few attempts have been made to reopen them, even as late as 1955. All the operating mines in the district are now located in Wisconsin and Illinois where lead is recovered only as a by-product of zinc mining.

Small pieces of *galena* can still be found in the dumps of the old mine workings along South Catfish Creek valley and in the Durango area. The old Beadle mine dump located in a ravine on the south side of Palmers Creek in the SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 33, T. 89N., R. 2E., yields good specimens of *sphalerite* and *galena*. Scattered pieces of *galena* can be picked up in the Dubuque Sand and Gravel Company quarry nearby in the SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 33. Ore and associated metallic minerals in this area are *galena*, *sphalerite*, *smithsonite*, *pyrite*, *marcasite*, *chalcopyrite*, *azurite*, *malachite* and *cerussite*. The wall rock of the mineralized veins includes *calcite*, *dolomite*, *chert*, *limonite*, *barite* and *gypsum*.

Considerable quantities of lead sulfide have been mined near North Buena Vista and Guttenberg in Clayton County and smaller amounts north of Waukon and northwest of Lansing in Allamakee County. The Allamakee County deposits are unusual in that they occur in much older rocks far outside of the boundary of the principal zinc-lead district as known today (see figure 1). The North Buena Vista mines date back to 1851. They are situated high on the west slope of the valley of a small creek just south of the village in the NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 28, T. 91N., R. 1W., Clayton County, and along the hillsides of Panther Hollow west of the village on

the Bakula and Breitbach properties in sec. 29, T. 91N., R. 1W. The ore was found in about the middle of the Galena Formation. A few horizontal drifts or adits, now almost completely caved in, and numerous vertical shafts are all that remain of these old mines. Many of the vertical shafts are 150 feet deep or more and still open with water in the bottom and very dangerous. The chances of finding lead around these old workings are slim owing to the heavy overgrowth of brush and timber. However, drive along Hefel Ridge west of town about 1¼ miles until you come to the Clarence Dean farm. This is on a side road in the NW¼ sec. 20, T. 91N., R. 1W. about half a mile north of the Great River Road which traverses the ridge. There is a covered shaft on the side of a ravine a little more than a quarter of a mile north of the farmhouse that was worked for lead in 1945-46. A residual clay in the bottom of the ravine has yielded many lead nodules as large as 1-2 inches in diameter. The lead lies loose in the clay, but you may have to dig into the clay to find it. A thin crust of white *cerussite* commonly surrounds the *galena* nodules. This lead is reported to have a small percentage of silver in it. The property owners are cordial to collectors, but permission is needed.

The Guttenberg deposits were opened about 1855. They occur in the bluffs of Miner's Creek and its branches 2 to 3 miles northwest of town in the N½ sec. 12, T. 92N., R. 3 W., and the NE¼ SE¼ sec. 12, and N½ SW¼ sec. 7 and SW¼ NW¼ sec. 7, T. 92N., R. 2W., Clayton County. Early investigations indicated the ore was disseminated in a bed about 2½ to 3½ feet thick at the base of the Galena Dolomite (Prosser Member) and about 120 to 140 feet above the Mississippi River level. The main producer in this district was the Holmes mine. This is located on the Richard Duwe farm 2½ miles up Miner's Creek Road from the south edge of Guttenberg. The house and barns are on the north side of the road in the NW¼ SW¼ sec. 7, T. 92N., R. 2W. Just up the hill in a grove of trees east of the farmhouse is the old adit, now completely caved in, and downslope from it, the mine dump, from which small pieces of weathered *galena* can be picked up. Much of the *galena* is in the form of cube-octahedral crystals. The best collecting is just after a good rain. Fine scalenohedron *calcite* crystals occur abundantly on this dump also. Visitors are welcome to collect, but ask at the house first.

If you have the opportunity, be sure to make the trip to look for lead ore at the old Allamakee County mines in northeastern Iowa, preferably in the spring before grass and weeds have covered the ground. The water-carved ridges, high bluffs and deep valleys of this section of the state comprise some of Iowa's most scenic country. The views from the uplands on the backroads are magnificent. Here you can see for miles across accordant ridges into deep wooded valleys. Some of the early

explorers passing up the Mississippi described the high bluffs on the Iowa side as a range of mountains! Even today the area is advertised as a "Little Switzerland". A few of the dome-like hills are still called mountains, such as Mt. Hosmer at Lansing. This visit will be highly inspiring and worthwhile even if your mineral discoveries are minor. However, when you visit these old mines if you are patient and persistent you'll find *anglesite*, *cerussite*, *limonite* and *sphalerite* associated with the *galena*, while crystalline *calcite* and drusy *quartz* are abundant in the bedrock.

The Allamakee County lead deposits occur in the Oneota Dolomite, the lower member of the Prairie du Chien Formation of Ordovician age. A little ore apparently occurs in the underlying Jordan Sandstone of Cambrian age. Mining activity was concentrated in two locations, the Mineral Creek area about eight miles due north of Waukon off Highway 76, and the Lansing area about five miles northwest of Lansing.

The Mineral Creek prospects are located on the Clem Brynes farm along the valley of Mineral Creek (Dry Creek), in the W½ NW¼ SE¼ sec. 13, T. 99N., R. 6W., Hanover Township. Stop at the farmhouse for permission. There are three groups of tunnels and one open cut. The tunnel openings are located less than a quarter of a mile south of the farm buildings, one in the bottom of a small ravine running to the creek and the other two farther south and about 30 feet higher on the valley slope. The open cut (probably a tunnel that caved) is located on the other side of the valley.

The first tunnel south of the farmhouse is the most accessible. Once inside you can stand up and scale a ladder to a higher level. Be extremely careful. The other tunnels have only crawl space and because rattlesnakes sometimes frequent them, I do not advise exploring the latter two where there is no room to maneuver. Once inside the cool recess of the first tunnel, you'll see *calcite* crystals sparkling around the walls. Small nodules of *galena* can be found in the calcite and shattered dolomite rock. A little *sphalerite* also has been reported here and earthy, white *anglesite* can be seen on weathered surfaces of the *galena*. Fragments of lead float can be found along the bed of the ravine just below the tunnel entrance, but it is difficult to recognize because of the camouflaging effects of weathering.

The Lansing mines are located on the Ed Walleser farm in a wooded tract on the east slope of a ridge in the NE¼ NW¼ sec. 10, T. 99N., R. 4W., Lansing Township. Stop at the farm house for permission and directions. This crevice was discovered in 1891 as a vertical north-south opening in the Oneota Dolomite. At least 500,000

pounds of lead reportedly were taken from these mines. A tunnel was opened at the north end and 3 or 4 vertical shafts 30 to 60 feet deep were dug at various intervals along the crevice. The remains of the tunnel can still be seen in the hillside and there is at least one open vertical shaft a short distance south of it, and perhaps one or two others farther south. The crevice is reported to be between 1,000 and 1,200 feet long. Lead can be picked up sparingly in irregular fragments and masses from weathered soil and rock in the vicinity of the shaft and tunnel. Glassy *cerussite* crystals are present with the *galena* in badly weathered, iron-stained dolomite and clay. Rhombohedral *calcite* also can be found here.

Occasionally chunks of lead ore weighing as much as several pounds are found in residual soils or in the glacial drift at other scattered locations in northeastern Iowa as far south as Jackson and Jones Counties.

Galena is the most important ore of metallic lead. Some of the main uses of lead are in storage batteries, as tetraethyl fluid in gasoline, as a metal alloy, for cable coverings, calking and solder, in varnish, oil refining, ceramics, plastics, paint pigments, pipes, ammunition, and for shielding against dangerous radiation in X-ray laboratories.

GLAUCONITE (hydrous silicate of iron and potassium, approx. $(KFe(SiO_3)_2 \cdot H_2O)$)

Glauconite sometimes called greensand or green earth, is a dull green mineral with a granular, earthy and amorphous structure. It usually occurs as tiny grains associated with *quartz* sand, limestone or shale. It has a glassy to dull luster and is opaque. Its streak is light green to greenish-white. *Glauconite* is very soft and can be crushed between the fingers. The hardness is 1 to 2 and the Sp.G. is 2.2 to 2.4.

Glauconite is widespread in sediments and may be concentrated rather heavily in thin beds. Some of the Cambrian sandstones in the Upper Mississippi Valley contain between 10 and 100 percent *glauconite*. Good exposures of glauconitic sandstone belonging to the Franconia Formation occur in the bluffs of the Mississippi River and its tributaries near Lansing and New Albin in Allamakee County. The upper and basal parts of the Burlington Limestone of Mississippian age found in natural exposures and quarries in Lee, Des Moines, Louisa and Keokuk Counties contain as much as 20 percent *glauconite* flakes and pellets.

This mineral can be classed as a low-grade source of potassium. The potassium in *glauconite* finds minor use as a plant fertilizer in some regions. In the past it has

been developed for this purpose on a small scale near New Albin. Another limited use of *glauconite* is in the water-conditioning industry.

GOETHITE (hydrogen iron oxide $HFeO_2$)

Goethite is a secondary mineral formed by weathering (oxidizing) of the iron minerals. It has a brilliant black to brownish-yellow color. It is commonly found in botryoidal or stalactitic aggregates with a fibrous inner growth structure in association with *pyrite*, *magnetite*, *siderite* and *limonite*. It also occurs in tiny, slender, prismatic, and vertically striated forms often as radiating groups known as "needle-ironstone" in *quartz* geodes and in septarian concretions on *calcite*. Another variety is found as soft, earthy, ocherous masses similar to *limonite*. The elongated prismatic crystals are orthorhombic. Cleavage is perfect parallel to the side pinacoid. *Goethite* may easily be mistaken for *limonite* or black botryoidal *hematite*. The luster of the black variety is shiny and varnish-like or dull and silky. The yellowish-brown streak distinguishes it from *hematite*. The mineral is brittle and fractures unevenly. It has a hardness of 5 to 5.5, although the porous ocherous variety has a hardness of about 1. The Sp.G. is 3.3 to 4.3. *Goethite* gives off water in a heated test tube. Because *goethite* has a crystalline structure, while *limonite* is amorphous, much material formerly classed as limonite is now believed to be *goethite*. Pseudomorphs of *goethite* after *pyrite* are common.

Thin linings of shiny black botryoidal *goethite* occur in cavities in the limonitic iron ore from the abandoned Iron Hill deposit two miles north of Waukon. When the *goethite* is broken a fibrous radial structure can be seen on some sectioned specimens. Occasionally the septarian concretions in the coal strip mines of Mahaska, Marion, and Monroe Counties yield tiny prisms of black, striated "needle-ironstone" *goethite* on *calcite*, either as individuals or as radiating clusters (plate 7C). The interior surface of some of the *quartz* geodes found near Keswick are liberally sprinkled with tiny black, prismatic *goethite* crystals. Slender crystals up to one-fourth inch long also have been found sparingly in the Warsaw Shale *quartz* geodes of southeastern Iowa.

Goethite is an ore of iron in Michigan, Minnesota, Colorado and in the Quebec and Labrador districts of Canada. It has no commercial value in Iowa, although the black prismatic crystals found in geodes and concretions are sought by collectors.

GOLD (Au)

Gold is one of the 20 or so native elements that are found in uncombined states



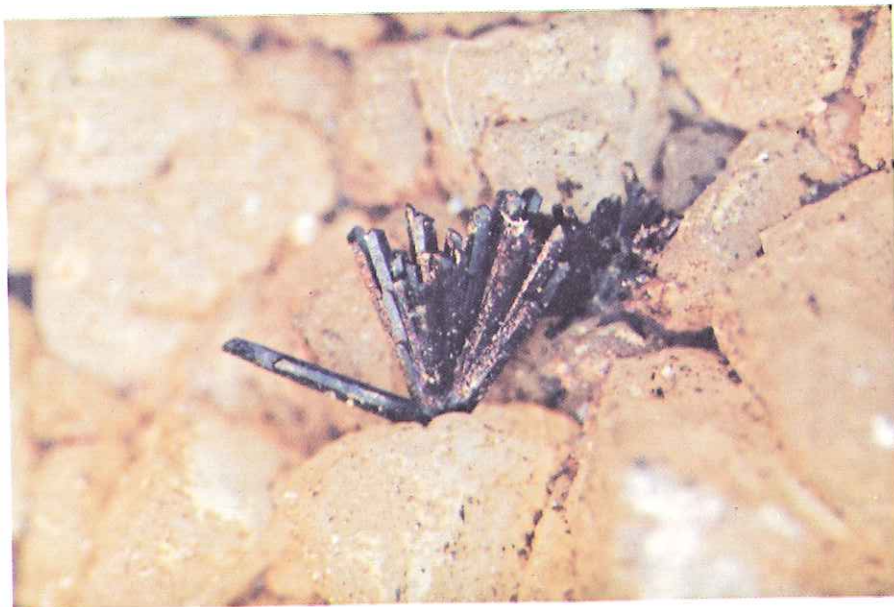
A. Brown *fluorite* penetration twins coated with *dolomite* and *pyrite* from the Volga locality.



B. Metallic *galena* fragments from the Dubuque area showing strong luster and cubic cleavage.

C. Radiating cluster of black, prismatic *goethite* (needle-ironstone) crystals set on light-colored *calcite*. Found in a septarian vug in the strip mines near Lovilia. X 7.0

D. White, woolly and hair-like *halotrichite* crystals on *pyrite* and *marcasite*. Marion County. X 5.0



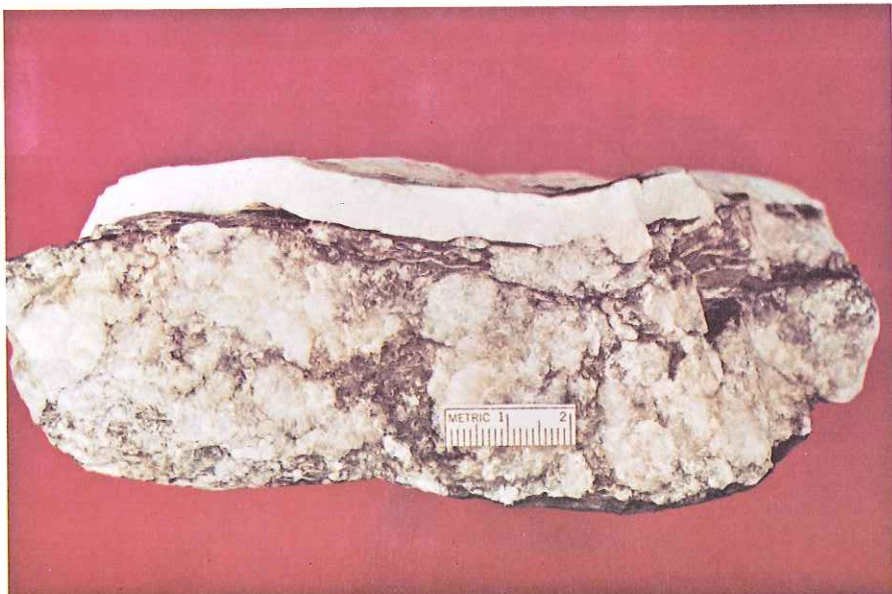


A. Typical *selenite* crystals showing penetration and contact (fishtail) twins. X 0.60



B. Network of tiny, prismatic *selenite* crystals from Pennsylvanian exposure across from Bells Mill Park. X 2.0

C. Massive rock *gypsum* and incorporated dark shale with thin band of fibrous white *satin spar* on top. Sperry gypsum mine. Metric scale.



D. *Pyrolusite* dendrites occurring on thin platy Gower Dolomite in northern Scott County. Scale in inches.



as minerals. It is a soft, sectile and malleable metal with a gold-yellow color. *Silver* is a common alloy and there may be traces of copper and iron. Usually *gold* occurs in irregular masses (nuggets), flattened scales and grains or dendritic shapes. It is found in igneous and metamorphic rocks, probably most abundantly in *quartz* veins, and in sedimentary placer deposits. Isometric crystals are rare. Cleavage is absent and the fracture is hackly. The color and streak are gold-yellow when pure, silver-white when alloyed with silver and orange-red when copper is present. The luster is metallic. *Gold* does not tarnish. The hardness is 2.5 to 3 and the Sp.G. is 15.6 to 19.3. Although *gold* may be confused with the metal sulfides *pyrite* and *chalcopyrite* and with weathered *biotite* mica flakes, it can be distinguished from them by its softness, malleability and high specific gravity.

The glacial drift and alluvial sands and gravels of Iowa contain particles of flaky placer *gold*. A few flecks of *gold* discovered on the banks of the Iowa River below Eldora in 1853 may have marked the first discovery of this mineral in Iowa. Traces of *gold* were later discovered along Otter Creek near West Union in 1858. Minute quantities were reported along Brush Creek, a tributary of the Volga River in Fayette County, and also along the Volga River near Fayette and farther downstream in Clayton County. Other Iowa localities where *gold* has been found are along the Des Moines River valley near Pella, Douds and Farmington; along Vesser Creek in northeastern Davis County; along the Big Sioux River at Klondike in Lyon County; and along the Little Sioux River near Correctionville in Woodbury County. A very small amount of *gold* has been found in the Upper Mississippi Valley zinc-lead district in association with *galena*, *sphalerite*, *pyrite*, *marcasite*, *barite* and *copper*.

The amount of placer *gold* concentrated at any one locality in the glacial drift and sands and gravels in Iowa is too small to make mining or panning economically profitable. In the past, Iowa has had its "gold rushes", but these reports have always proven to be unfounded rumors.

GYP SUM (hydrous calcium sulfate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$))

Gypsum occurs in four forms based on differences in physical structure, although their chemical composition is the same, hydrous calcium sulfate. Massive bedded forms are called *rock gypsum*. Rock gypsum usually is dull colored and has impurities such as clay, calcium carbonate and silica. Very fine grained massive forms that usually are white are called *alabaster*. Coarsely crystallized forms usually found as free crystals in shales are called *selenite*. Fibrous forms with silky luster are called *satın spar*.

Gypsum crystals commonly are flat, parallelogram-shaped or diamond-shaped with beveled edges (plate 8A). Crystallization is monoclinic with perfect cleavage in one direction, yielding thin polished fragments, and less evident in two other directions. Crystals are brittle and break with a conchoidal or splintery fracture. The luster is glassy to pearly. The color usually is white or gray, but may be yellow or red. Colorless, transparent crystals also are rather common. The streak is white. *Gypsum* is so soft it is easily scratched by the fingernail. It has hardness of only 2 on the Mohs scale. The Sp.G. is 2.3 to 2.4. When heated in a test tube gypsum gives off much water. It is soluble in hot hydrochloric acid.

Thick beds of rock gypsum resembling gray limestone occur in near-surface deposits at Fort Dodge in Webster County. This deposit has a particular banded appearance with alternating light and dark layers. The freshly broken rock has a glistening surface. Stripping methods are used to reach the gypsum. Massive rock gypsum also has been obtained from deep underground mines in the Warsaw Formation at Centerville in Appanoose County and in the Wapsipinicon Formation near Sperry in Des Moines County (plate 8C). The Centerville mine has been abandoned for many years. The Sperry mine currently is very active and has large reserves. Deep wells in southern and central Iowa indicate that massive *gypsum* and *anhydrite* deposits are widespread in the St. Louis-Spergen-Warsaw Formations of Mississippian age and in the Cedar Valley and Wapsipinicon Formations of Devonian age.

Selenite crystals can be found at many places in Iowa. The shales of Pennsylvanian age in southern Iowa are especially good collecting areas as are the shale pits in the Juniper Hill Member of the Lime Creek Formation at Mason City. The best places to look are on weathered slopes of the shale outcrops or in worked-out sections of the clay pits where weathering has been active for some time. Often the largest crystals are found on flats at the base of the slopes where water accumulates and evaporates. The crystals have characteristic flattened diamond shapes and may have clay or coal inclusions. In some localities twinned crystals are abundant as swallow-tailed or fish-tailed prisms. Some of the strip mines in the Lovilia area yield clear, prismatic *selenite* crystals up to one inch long on brown, iron-coated *calcite* or *dolomite*.

Large and nearly perfect crystals 3 to 6 inches long were observed in carbonaceous shales of Pennsylvanian age overlying the Ste. Genevieve (Pella) Formation in an abandoned quarry in the S½ NW¼ sec. 11, T. 76N., R. 17W., Mahaska County. Two excellent collecting locations in Dallas County occur along

the county road three miles north of Dexter in the NE¼ sec. 18, T. 78N., R. 29W., and along the road bordering the west side of the Des Moines River valley in the NW¼ sec. 11, T. 81N., R. 26W., approximately two miles southeast of Highway 89. An abandoned clay pit opened in the Sheffield Shale about four miles southeast of Sheffield, east of Beaverdam Creek in the SW¼ SE¼ sec. 7, T. 93N., R. 19W., Franklin County, yielded abundant crystals. A roadcut in the Maquoketa Shale along the west side of Highway 52 about 1½ miles southeast of Bellevue State Park literally sparkles with hundreds of twinned *selenite* crystals, some up to four inches long. Large single and twinned crystals with clay inclusions also are present in shales of Cretaceous age in a roadcut along Highway 12 about three miles south of Hawarden in Plymouth County. *Selenite* is abundant at many other Cretaceous shale exposures along Highway 12 in Sioux and Hancock Townships in Plymouth County. At one locality in the SW¼ SE¼ sec. 34, T. 92N., R. 49W., *selenite* occurs on the slope of the bluff in seams or crusts of short columnar prisms about half an inch thick weathering out of the shale. The Warsaw Formation geodes contain thin, elongated clear *selenite* crystals up to 1½ inches long. They may be striated lengthwise. They usually are implanted on *chalcedony* or *quartz*. Tiny, lace-like aggregates of prismatic, striated, clear and iron-stained *selenite* were observed on black shales surrounding *pyrite* concretions in the Pennsylvanian exposure along the Boone River across from Bells Mill Park north of Stratford (plate 8B).

Numerous thin bands of *satin spar* parallel to the bedding planes occur in the Fort Dodge *gypsum* deposit and were also observed in the Sperry mine (plate 8C). Much of the *gypsum* from the Sperry mine appears to be *alabaster*. It is unusually white, finely crystalline and is easily carved with a pocket knife.

Heating or calcining *gypsum* to make a powder for *gypsum* plaster has been in use for at least 5,000 years. It was used in building the Great Pyramid of Cheops in Egypt some 3,000 years before Christ. The Greeks of pre-Christian time also made abundant use of *gypsum* plaster in constructing their temples. Through the centuries the utility of *gypsum* has continued to increase. Today *gypsum* is used extensively in the construction industry, especially for making wallboard, sheathing and plasters for housing. Some other uses are as a retarder to control the setting of portland cement, as a soil additive, in the pottery trade for making molds, as blackboard chalk, as insulating material, in surgical bandages and casts, in dental work and many other minor uses.

Iowa has long been one of the major *gypsum* producers in the nation based largely on the Fort Dodge surficial deposits. However, the growing market in the construction industry after World War II brought about increased exploration for

new sources. Interpretation of well samples and mapping of the deeply buried *gypsum* and *anhydrite* deposits by the Iowa Geological Survey led to test drilling at several locations beginning in 1957. The *gypsum* mine near Sperry is a direct result of this preliminary mapping. Annual Iowa *gypsum* production from both the Fort Dodge and Sperry mines is well over a million tons.

HALOTRICHITE (hydrous sulfates of iron and alum($\text{FeSO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 22\text{H}_2\text{O}$))

Halotrichite is a white, soft and woolly-like mineral occurring as radial or matted aggregates of hair-like crystals on *pyrite* and *marcasite* (plate 7D). It is formed as a weathering product of the iron sulfide. A hand lens or a microscope is needed to see the crystals clearly. An old term for the *halotrichite* group of minerals is *hair salts*. There are several other minerals in this group which substitute magnesium, manganese, zinc, chromium and nickel and combinations of these elements for iron.

The crystal structure of *halotrichite* is monoclinic. The mineral usually is white, but may be yellowish or greenish. It has a vitreous luster. The taste is astringent. The hardness is 1.5 and the Sp.G. 1.89 to 1.95. It is soluble in water and thus usually is found as powdery white encrustations rather than in delicate hair-like crystals on the surface of iron sulfides. Where conditions are favorable such as in sheltered crevices or in mine shafts that provide protection from the elements the crystals may grow to a good size. As an experiment, collect a batch of *pyrite* or *marcasite* from various localities in the strip mines around Knoxville or Oskaloosa and store it in a damp drawer in a basement for a year or two leaving it undisturbed. Tiny, white hair-like *halotrichite* crystals up to 3-4 millimeters long may grow on the surface of the sulfides.

Probably the best place to look for *halotrichite* in Iowa is in the southeastern coal-mining areas in Marion, Mahaska, Monroe, Van Buren and Appanoose Counties where *pyrite* and *marcasite* are abundant. Other hydrated ferric sulfates such as *melanterite* (copperas) and *copiapite* may be associated with the *halotrichite*. *Gypsum* is another mineral associated with *halotrichite*. These minerals may have the same fibrous or hair-like structure so that they are difficult to distinguish.

HEMATITE (iron oxide Fe_2O_3)

Hematite or red iron ore occurs in a variety of forms from soft, dull-red earthy material to hard, steel-gray to black metallic masses and crystals. Its habit commonly is botryoidal, scaly and oolitic, but it may be columnar, granular,

stalactitic, lamellar and earthy or compact. Crystallization is hexagonal-rhombohedral. Crystals usually are tabular and may show rhombohedrons or scalenohedrons on the borders. They may be thin or thick and arranged in radial aggregates to form rosettes. The faces of these tabular crystals are finely striated parallel to the edges. There is no cleavage but the striations cause a parting or pseudo-cleavage. The luster usually is metallic or dull. *Hematite* generally is opaque except on very thin edges where it may be translucent in red. The streak is always red or reddish-brown even in black varieties and this is one of the most useful properties in identifying it. The hardness is 5.5 to 6.5 and the Sp.G. 4.9 to 5.3.

Metallic *hematite* probably is not common in Iowa although a massive type has been reported from the Iron Hill limonitic ore deposit north of Waukon in Allamakee County. Pieces of massive, granular *hematite* have been picked up from the glacial drift south of Rice Lake in Winnebago County and in the gravel pit south of the Iowa City airport, and doubtless can be found elsewhere in the drift. A reddish-brown oolitic *hematite* rock can be found in the Mississippi River gravels. In appearance it somewhat resembles red *jasper*, but lacks the conspicuous glassy luster and subconchoidal fracture of *jasper*. The oolitic texture is characteristic. It can be seen easily with a hand lens on a fresh surface. Some of the oolites are black or steel-gray metallic *hematite*, others may be dull red or bright red. The cementing substance may be *hematite* or silica. The percentage of silica present varies. These specimens are metamorphosed sediments and will break right through the oolite grains. A small amount of *magnetite* frequently is associated with the oolitic *hematite*. In some specimens a greenish-gray mineral, probably *chamosite*, or a similar iron silicate such as *greenalite*, occurs in oolitic form with the *hematite*. Much of this oolitic *hematite* gravel probably was derived from the Mesabi and Cuyuna iron ranges of northern Minnesota from where it was rafted southward by glacial ice and concentrated along meltwater streams.

Thin bands of nodular or concretionary *hematite* have been found in the Cretaceous sandstone outcropping along Spring Creek about a mile west of Lewis in the SE/cor. NW¼ sec. 9, T. 75N., R. 37W., Cass County. Sandstone concretions cemented by *hematite* occur in exposures of the Cretaceous rocks along the Big Sioux River in Woodbury and Plymouth Counties. Scattered *hematite* concretions also can be picked up in the old strip mines around Oskaloosa. An earthy form of *hematite* having a reddish-brown color and known as *red ochre* can be found in a few places in Iowa. It probably occurs in the Waukon deposit and is scattered in the shales and sandstones of Pennsylvanian age in the southern part of the state. A few geodes in southeastern Iowa also have been found with the reddish powder of

hematite on *calcite* or *quartz*. This type of *hematite* usually is soft enough to mark paper easily. A red ochre that is the weathering product of iron-oxide cement occurs on the Red Rock Sandstone northeast of Monroe, in Jasper County.

The dark and compact variety of *hematite* occurring chiefly as sedimentary and residual deposits in other regions of United States is the main ore used in supplying the metal for iron and steel products. Minnesota, Alabama, Wyoming and Utah are the principal producing states.

LIMONITE (hydrrous oxide of iron $\text{FeO}(\text{OH}) \cdot n\text{H}_2\text{O}$)

Limonite is a secondary deposit resulting from the alteration of other ores or minerals containing iron, through exposure to moisture, air and organic acids. Other names for *limonite* are brown iron ore, brown *hematite* and bog iron ore. *Limonite* is an amorphous mixture of various hydrates of iron. It has no cleavage. The mineral structure is highly variable and may be massive, concretionary, botryoidal, earthy, stalactitic or cellular. The color is dark brown to black on fresh surfaces and yellow to light brown on weathered surfaces, but the streak is always yellowish-brown. *Limonite* is opaque. The luster is glassy to dull. An earthy form of *limonite* called *yellow ochre* containing a large percentage of clay may be soft enough to mark paper. The brown or black unweathered mineral has a hardness of 5 to 5.5 and may be almost too hard to be scratched by a knife. The Sp.G. ranges from 2.7 to 4.3.

The discovery and development of Iowa's only iron mine makes an appealing story of the enterprise and perseverance of one of our pioneer residents, Charles Barnard, of Waukon. A nurseryman by trade, he probably stumbled across the iron ore deposit on Iron Hill two miles north of town while looking for nursery stock or for building stone. Despite the skepticism of others, Barnard, in 1875, insisted that the hill north of Waukon contained a remarkable deposit of iron ore. He was right, of course, but much testing and promotional work were needed to prove it. He enlisted the aid of the editor of the Waukon newspaper to broadcast the discovery, and devoted much time to corresponding with men of practical means, attempting to interest them in making an investigation of the deposit which he was sure would be a big boost to the community. Eventually enough money was raised for preliminary exploration. Numerous test pits were dug and analyses run which showed a large deposit of suitable grade ore. The first mining leases were made in 1898, the year he died.

When the Missouri Iron Company completed its concentration plant on Iron Hill in 1913 estimates of reserves as high as 10 million tons were reported. Using a beneficiation process consisting of drying, roasting and magnetic separation, the company obtained a product containing 55 percent iron. The concentrate was shipped to Chicago, Milwaukee and St. Louis. The shipment records are not complete, but at least 67,000 tons of concentrate reportedly were shipped. The last recorded shipment was in 1918, although some activity continued through 1922. Subsequently, the plant was dismantled and the equipment sold, marking the end of Iowa's brief flurry in iron ore mining.

The Iron Hill deposit is located along Highway 9 approximately 1½ miles north and east of the Waukon city limits in sec. 17, T. 98N., R. 5W., Allamakee County. This is one of the best places in the state to collect *limonite* (plate 9A). *Goethite* and *hematite* also are present. The deposit occurs in the Prosser Limestone, the lower member of the Galena Formation of Ordovician age. It forms a crescent-shaped ridge concave to the east and about half a mile wide and three quarters of a mile north and south. A fine, grayish, loess-like material overlies the ore. The ore can be seen and collected in the narrow roadcut along Highway 9 near the crest of the hill. This hill has an elevation of 1,340 feet and is one of the highest points in northeastern Iowa. This is a replacement deposit in highly fractured limestone. The *limonite* occurs as concretions up to boulder size, cellular masses and fracture fillings. It was deposited from ground water that dissolved the limestone, leaving rounded pieces that were partly decomposed and replaced by *limonite*. Clay is present in cavity fillings and as residual cores of concretions. Irregular nodules and lenticular masses of residual *chert* have been partly replaced and coated by *limonite*. Botryoidal *goethite* occurs in the cavity linings.

An interesting stalactitic form of *limonite* has been collected from a roadcut south of Vernon Springs on the south side of the Turkey River in the NW¼ SW¼ sec. 34, T. 98N., R. 11W., Howard County (plate 9B). Moderate-sized boulders of an earthy, stalactitic and cellular type of *limonite* have been seen in a few places on top of the Silurian Dolomite or in the glacial drift southeast of Maquoketa. One locality collected from was on the Harold Wilms farm in the SE¼ SE¼ SE¼ sec. 30, T. 84N., R. 3E., Jackson County. Fragments and small masses of this type of *limonite* have been reported at many other localities in Jackson County, especially along the valley of Brush, Farmer's and Lytle's creeks north of the Maquoketa River. The Iron Hills community 10 miles northwest of Maquoketa probably took its name from the abundance of *limonite* found there.

Concentrations of *limonite* have been found in thin layers interbedded in the Dakota Sandstone of Cretaceous age exposed at several places in Cass, Montgomery and Guthrie Counties in southwestern Iowa. The Cretaceous sediments of this area also contain "puddingstone" or "peanut conglomerate" beds which have *limonite* as the cementing material (plate 15A). Some collecting locations for this type of *limonite* are in a deep ravine just south of a gravel road near the N¼ cor. NE¼ sec. 33, T. 79N., R. 30W., Guthrie County; north of the same road in the SW¼ SW¼ sec. 28, T. 79N., R. 30W., Guthrie County; the NW¼ NE¼ sec. 33, T. 75N., R. 36W., Cass County, along the bank of a branch of Seven Mile Creek; the SE¼ SE¼ sec. 18, T. 71N., R. 38W., Montgomery County, at the edge of the Nishnabotna River valley; and the S½ sec. 30, T. 71N., R. 38W., Montgomery County, at the east edge of Coburg.

Limonite is a minor source of iron ore in the United States. It is also used as a yellow pigment in paints and enamels. The Waukon iron ore probably comprises a low-grade commercial deposit even though it is not being worked now. Other smaller deposits of this type are believed to occur in Howard County and in Fillmore County in southeastern Minnesota north of Cresco and Decorah. Some of the Fillmore County deposits are currently active.

MAGNETITE (ferrous and ferric iron oxide Fe_3O_4)

Magnetite or magnetic iron ore is a black, crystalline, granular or massive mineral found in igneous and metamorphic rocks, pegmatites and sands. Its most distinguishing characteristic is its strong magnetism. Crystals are isometric, usually occurring in octahedrons and less commonly in dodecahedrons. Triangular marks or striations may be seen on the crystal faces. *Magnetite* is iron-black and has a metallic luster. The hardness is 5.5 to 6.5 and the Sp.G. 5.2. The mineral is brittle and the fracture is subconchoidal to uneven. There is no cleavage, but a parting parallel to the octahedron faces may be observed. The streak is black. *Magnetite* generally is opaque. A rare variety of *magnetite* called *lodestone* is a natural magnet possessing polarity, that is, it has two magnetic poles, north and south, just like the earth.

Magnetite is widespread as tiny grains in igneous and metamorphic rocks. When the rocks weather and break down the mineral may be concentrated as black sands. Irregular lenses of black *magnetite* sand have been collected from sandbars in the Missouri River valley near Council Bluffs and doubtless can be found at many other places up and down the river. These black sands probably were washed out of the

PLATE 9



A. Cellular *limonite* boulder from the Waukon Iron Hill exposure.



B. Stalactitic *limonite* found in exposure near Vernon Springs. Scale in inches.

C. An unusually large specimen of *millerite* on crystalline *calcite*. Coralville quarry, Johnson County. X 1.0



D. Capillary *millerite* set on clear and iron-stained *quartz* crystals and light-gray *chalcedony*. A few *pyrite* grains included. Ollie quarry, Keokuk County. X 0.65



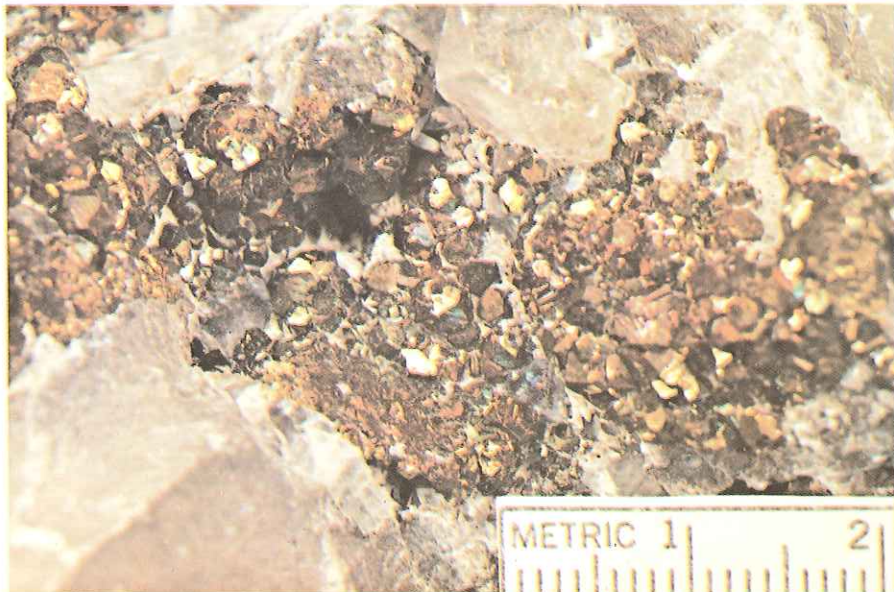


A. Combination cube-octahedron *pyrite* crystals weathering to *limonite* or *goethite* from the Maquoketa Shale near Dubuque. X 1.0



B. Typical *pyrite* crystals found in strip mines near Oskaloosa. X 1.5

C. *Pyrite* crystals, partly iridescent, on *calcite* and limestone from the Cedar Valley Formation at Iowa City. Metric scale.



D. *Quartz* druses on *calcite* and limestone. Little America mine, Washington County. X 1.1



glacial drift and weathered sedimentary rocks such as the Dakota Sandstone and from igneous and metamorphic rocks hundreds of miles upstream. The Mississippi River valley, too, has unconfirmed reports of black magnetic sands. These river sandbars can be tested with a magnet by moving it back and forth just over the top of the sand. A paintbrush serves well in cleaning the sand off the magnet.

The author found clusters of tiny metallic *magnetite* crystals with triangular faces of the octahedron in the oolitic *hematite* rocks of the Mississippi River gravel deposits. These octahedron *magnetite* crystals are observed best with a microscope, but can be seen with a hand lens if you look closely. *Magnetite* can also be found as an accessory mineral in many kinds of igneous and metamorphic rocks. It is found most abundantly in the darker iron-rich rocks. Crush fragments of these rocks and repeat the magnet test. Another interesting experiment is to take a specimen of common sand from any pit or riverbank exposure and check it for *magnetite*. A surprisingly large amount of *magnetite* may be found. Layers of black sand in gravel pits also may contain at least minor quantities of *magnetite*.

MILLERITE (nickel sulfide NiS)

Millerite, sometimes called "capillary pyrite", occurs as tiny needle-like to hair-like brass-yellow crystals. It usually is found with *calcite* crystals in limestones in aggregates of delicate radiating crystals or may be interwoven like tufts of hair, forming the so-called "birds nest" *millerite*. Cleavage is perfect in two directions, but this cannot be seen without the aid of a very powerful microscope. Rarely is the mineral coarse enough to show its hexagonal form. Capillary crystals are elastic. The luster is metallic. The hardness is 3 to 3.5 and the Sp.G. is 5.3 to 5.6.

In Iowa *millerite* usually is found in vuggy or brecciated limestones as radiating, hair-like brushes or as clusters of interwoven filaments in association with *calcite* or *chalcedonic quartz* (plate 9C). Beautiful specimens of *millerite* brushes up to 2-3 inches long have been found in the Davenport Member of the Wapsipinicon Formation, a highly brecciated, fine-grained limestone associated with a greenish shale in a quarry at Coralville (plate 9B). Unfortunately, this quarry has been closed to visitors. Vugs and irregular masses of *chalcedony* occurring in the lower Keokuk Formation in a quarry northeast of Ollie have yielded fragile interwoven clusters of "birds nest" *millerite* as well as straight and curved filaments. Here the *millerite* rests on clear *quartz* crystals and on gray botryoidal *chalcedony* as well as on *calcite*. A small amount of dark-colored, radiating, needle-like *millerite* also was found embedded in *calcite* in the Spergen Dolomite in the quarry north of New

Sharon. Botryoidal *chalcedony* and granular *pyrite* are associated with the *millerite* and *calcite*. Another collecting location for *millerite* is the Camanche quarry in the St. Louis Formation about three miles west of Farmington at the center NE¼ sec. 5, T. 67N., R. 8W., Van Buren County. Here *millerite* is embedded in *calcite* crystals in veins in a rather thick-bedded, gray limestone.

Millerite has been found in geodes containing *calcite* crystals in the Keokuk Limestone below the main geode beds in the Warsaw Shale, and in vugs and pseudogeodic cavities lined with *quartz* and *chalcedony* in the Montrose Chert (lower Keokuk Formation) near Keokuk.

Some geodes in the Warsaw Shale contain slender crystals of *pyrite* and *marcasite* that may easily be mistaken for *millerite*. If it is iron sulfide, the *quartz* and *calcite* crystals surrounding the *pyrite* may show tell-tale iron-staining. Both *pyrite* and *millerite* may occur in the same geode. *Millerite* also has been observed in association with *calcite*, *sphalerite* and *galena* in the Platteville Formation in the Upper Mississippi Valley zinc-lead district.

Millerite is reported to be a minor source of nickel, but it is never found in large quantities. It is fairly scarce in Iowa and has no commercial value. Most of the nickel consumed in United States is obtained from the Sudbury district of Ontario, Canada, and from Cuba. Principal United States nickel production is in Oregon. The largest use of nickel is for alloys in non-iron metals such as copper, zinc and aluminum, and in stainless steel for manufacture of industrial, transportation and household equipment.

PYRITE and MARCASITE (iron disulfide FeS₂)

Pyrite is a shiny, pale, brass-yellow mineral that crystallizes in the isometric system in the form of cubes or octahedrons and pyritohedrons (plates 10A and 10B). It has a metallic luster and is opaque. The surface may tarnish brown or become iridescent. The crystal faces often are striated with fine parallel lines. *Pyrite* is widespread in all kinds of rocks. It is particularly abundant as massive and granular aggregates. It also occurs in veinlets, in globular and stalactitic form and as scattered individual crystals. *Pyrite* is nicknamed "fool's gold" because it resembles gold. However, *pyrite* is brittle and breaks into small pieces. The streak of *pyrite* is greenish-black. *Pyrite* has a hardness of 6 to 6.5 and can scratch ordinary glass. The Sp.G. is 4.9 to 5.02.

Marcasite has the same chemical composition as *pyrite*, but crystallizes in the orthorhombic system. It has about the same pale brass-yellow color, although *marcasite* usually is a shade whiter on fresh surfaces and for this reason it is called white iron pyrite. Sometimes it has a greenish hue when weathered. Groups of twinned *marcasite* crystals often assume "cockscomb" or spear-head forms that distinguish them from the cube-shaped *pyrite* crystals. *Marcasite* also is very common as nodules and globular masses with a radiating inner structure. Both *pyrite* and *marcasite* disintegrate on exposure to air but *marcasite* crumbles faster than *pyrite* and causes paper trays to turn brown from the sulfuric acid released during oxidation. *Marcasite* has a hardness of 6 to 6.5 and a Sp.G. of 4.88. When heated both *pyrite* and *marcasite* give off a distinctive sulfide "rotten egg" odor.

Pyrite and *marcasite* are widespread in Iowa shales, marls, limestones, sandstones and coals. They are especially abundant in the coal-bearing formations of Pennsylvanian age in southern Iowa in Marion, Mahaska and Dallas Counties. Good specimens can be found weathering out of the refuse dumps of many old coal strip mines in the Oskaloosa area (plate 10B and 11A). An old quarry about a mile south of Tracy formerly yielded masses of good *pyrite* crystals from shales overlying the limestone. The area south of Adel in Dallas County is noted for yielding beautiful clusters of *pyrite* crystals as large as a fist from a blue clay in the banks of streams. Apparently some of these crystal aggregates were fossils that were replaced by the iron sulfide.

Very beautiful crystal aggregates of iridescent *marcasite* and *pyrite* associated with *calcite* and *barite* can be found in coal balls in the coal strip mines of Mahaska, Marion and Monroe Counties (plate 15B). Coal balls are spherical and irregular concretions composed of intermingled plant fragments such as roots, leaves, stems, seeds and spores embedded in a matrix of calcium and magnesium carbonate and iron sulfide. Although this is a form of petrification, the fossil plants embedded in the coal-ball matrix are not petrified by having been replaced by minerals. The cell walls of the plant tissue in the coal balls still occur in an almost unaltered organic condition with mineral matter infiltrating and filling the cells (plate 11B). The concretions range from the size of a small marble up to three feet in diameter, averaging about the size of a softball or volleyball. Not all coal balls contain good *marcasite* and *pyrite* crystals. Any of the operating mines in the Knoxville-Oskaloosa areas may provide profitable collecting. Specific locations the author has collected from are the dumps at the tipple of the Mich Coal Company strip mines along the C.R.I. & P. Railway 2½ miles east of Oskaloosa and in the strip mines in

sec's 10 and 11, T. 75N., R. 15W., Mahaska County; at the Lost Creek Coal Company mine No. 1 on the east side of Highway 137 in sec. 7, T. 74N., R. 15W., Mahaska County; at the Star Coal Company mine in the SE¼ sec. 14, T. 74N., R. 17W., Mahaska County, on the north side of the county road about 5½ miles east of Bussey; and at the Mich Coal Company mine about 6½ miles west of Eddyville in the SE¼ sec. 12, T. 73N., R. 17W., Monroe County. Coal balls also were found at several other places in strip mines around Knoxville that are now abandoned.

Some unusually well-developed *pyrite* crystals that are combination forms of cubes and octahedrons measuring up to ¾ inch in diameter were found in the lower part of the Maquoketa Shale just east of the Dubuque County Fairgrounds (plate 10A). This exposure is located off old Highway 20 on the south slope of Catfish Creek valley in the NW¼ NE¼ sec. 31, T. 89N., R. 2E., Dubuque County. The tarnished, bronze-brown crystals weather out of the light shale easily. Where the weathering has progressed far enough some of the crystals might be classed as pseudomorphs of *goethite* after *pyrite*. Traces of red *hematite* can be observed on the surfaces of these crystals.

Pyrite commonly is associated with *calcite* vugs in limestone quarries such as in Pint's quarry near Raymond and in many other quarries in eastern and southeastern Iowa (plate 10C). *Pyrite* and *marcasite* are some of the most common minerals in the zinc-lead ore-bearing dolomites in the lower Galena Formation in the Dubuque area. The Warsaw Shale geodes in southeastern Iowa also contain *pyrite* and *marcasite*. The *pyrite* generally occurs as small striated cubes and the *marcasite* as long, flat, striated crystals or cockscombs. Both minerals frequently occur in slender capillary crystals either in clusters or individually. *Pyrite* may also be found completely replacing the organic matter of fossils or plants. Pyritized brachiopods, corals and wood can be found at many places in the Pennsylvanian bituminous shales and coal strata around Knoxville and Ottumwa.

In some parts of the United States *pyrite* is mined for its sulfur which is used in the manufacture of sulfuric acid. It has been speculated that the iron sulfide found in Iowa coals and in the zinc-lead district around Dubuque could be utilized as a by-product for manufacture of sulfuric acid, but nothing has come of this yet. Sulfur has numerous uses in fertilizers, chemicals, iron and steel, rayons, petroleum, papers, bleaches, celluloid, dyes, explosives, medicine, plastics and many other products.

PYROLUSITE (manganese dioxide MnO₂)

Pyrolusite is a secondary mineral formed by oxidizing of rocks and minerals containing manganese, or it may be deposited directly from groundwater. It is associated with manganese and iron oxides and hydrous oxides such as *manganite*, *psilomelane*, *limonite*, *hematite* and *goethite*. It occurs in crystalline and fibrous masses, generally steel gray or black in color with a metallic luster and sooty black streak. It is opaque and may be soft enough to rub off on your fingers. The massive varieties have a hardness of 2 to 6 and the crystalline varieties 6 to 6.5. The Sp.G. is 4.4 to 5. *Pyrolusite* also occurs as thin fern-like coatings or films on the bedding planes and fissures of limestones, dolomites, siltstones and shales (plate 8D). Only this latter type, known as dendrites, are easy to find in Iowa. They are often mistaken for fossil ferns or leaves.

The quarries in the Niagaran dolomites of Silurian age around Princeton are the "type" locality for *pyrolusite* dendrites in the United States. Unusually fine slabs can be found in the Gower Formation, a yellowish-brown dolomite, in a quarry in the NW $\frac{1}{4}$ sec. 17, T. 80N., R. 4W., about a half a mile east of Highway 61 in northern Scott County. Another good source is the quarry opened in the Gower Dolomite two miles south and half a mile east of Grand Mound, in the SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 29, T. 81N., R. 3E., Clinton County. A wide-faced chisel is the best tool for splitting the bedded dolomite into thin slabs. These slabs can be sawed into almost any shape to make tabletop or wall decorations.

Other collecting locations for the dendrite type of *pyrolusite* are hardly worth mentioning because the mineral is so widespread. Dendritic growths of *pyrolusite* also have been reported on the faces of *quartz* crystals and to a lesser extent on *calcite* crystals and *chalcedony* in the Warsaw Shale geodes in southeastern Iowa. The dendrite growths enclosed in clear *chalcedony*, *agates* and some *cherts* are called *moss agate* and can be found sparingly in Iowa gravel pits.

A black earthy type of manganese oxide called *wad* is reported to occur in mineralized crevices in the limestones in the Dubuque area and in thin layers in the abandoned Waukon iron-ore pits. Elsewhere, manganese oxide deposits often occur in irregular bodies in residual clays.

Manganese is important in producing and toughening steel, as an alloy with copper, aluminum and magnesium and for manufacturing dry-cell batteries and chemicals. No commercial deposits of manganese have been found in Iowa.

QUARTZ (silicon dioxide SiO₂)

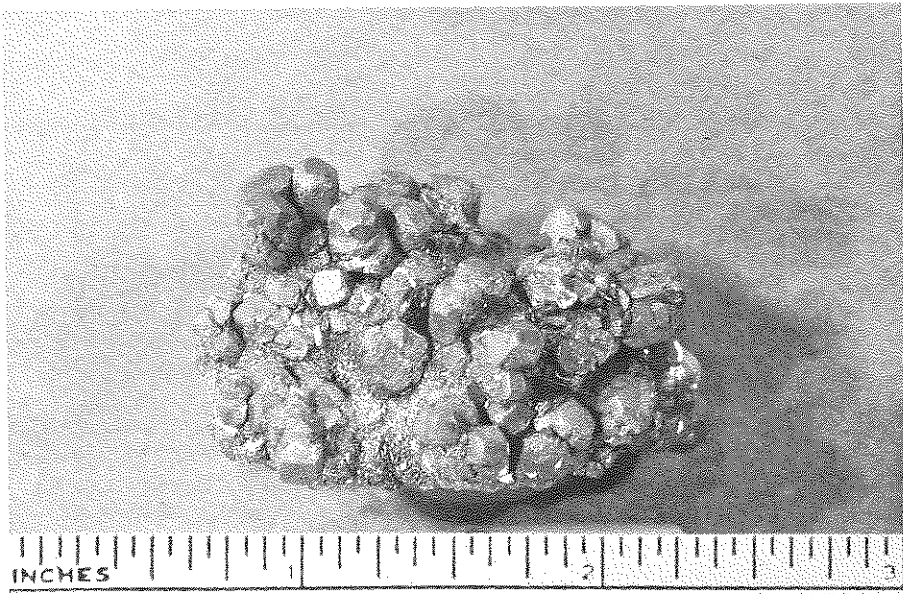
Quartz is one of the most abundant minerals and occurs in many forms and colors in all kinds of rocks. There are two principal types based on appearance—coarsely crystalline varieties and microcrystalline or massive varieties. The coarsely crystalline varieties include well developed crystals and irregular crystalline masses. The crystals have a hexagonal-rhombohedral form occurring as six-sided prisms with pointed pyramid-like ends. The prism faces of crystals commonly have horizontal striations. Pure *quartz* is colorless and transparent. Impure varieties are shades of yellow, pink, red, brown, green, violet, blue and black and range from transparent to opaque. *Rock crystal* is the name given to pure *quartz* crystals. Violet crystals are called *amethyst*. Gray and black crystals are known as *smoky quartz*. Yellow crystals are known as *citrine*. Masses of the crystallized material that are white or pink are known as *milky* and *rose quartz*. The luster is glassy to greasy. Cleavage is rarely seen. The mineral is brittle and breaks with a subconchoidal fracture. The streak is white. *Quartz* has a hardness of 7 and the Sp.G. is 2.65.

Examples of microcrystalline *quartz* are *chert*, *flint*, *chalcedony*, *agate*, *jasper*, *carnelian* and *silicified wood*. The crystals in these varieties are too small to be seen without the aid of a high-powered microscope. This type of *quartz* may be tougher than crystallized *quartz*. It usually has a dull or waxy luster unless polished by wind or wave action. It also has a slightly lower Sp.G., varying between 2.58 and 2.64.

Quartz is widespread in Iowa. It is the chief mineral of sand and gravel deposits, probably because the hardness, lack of cleavage and insolubility make it resistant to weathering and favor its concentration near the surface. *Quartz* also is found in sandstone, conglomerate and quartzite formations and as the inner mineral matter of vugs and geodes (plate 13C).

As many as 18 different minerals have been identified in the geodes of the Keokuk area according to Sinotte (1969), although *quartz* is by far the most profuse. The geodes can be found in bands in the lower Warsaw Shale and Keokuk Limestone Formations along the west bluff of the Mississippi River in Lee County and at several other places where these formations are exposed in the beds and valley walls of the Des Moines and Skunk Rivers and their tributaries, and in a few quarries in Lee, Van Buren, Des Moines, Henry and Keokuk Counties. The following are some specific collecting locations:

1. Along the stream bed and banks of Mud Creek about one mile northeast of Lowell in sec.'s 22 and 27, T. 70N., R. 5W., Henry County.

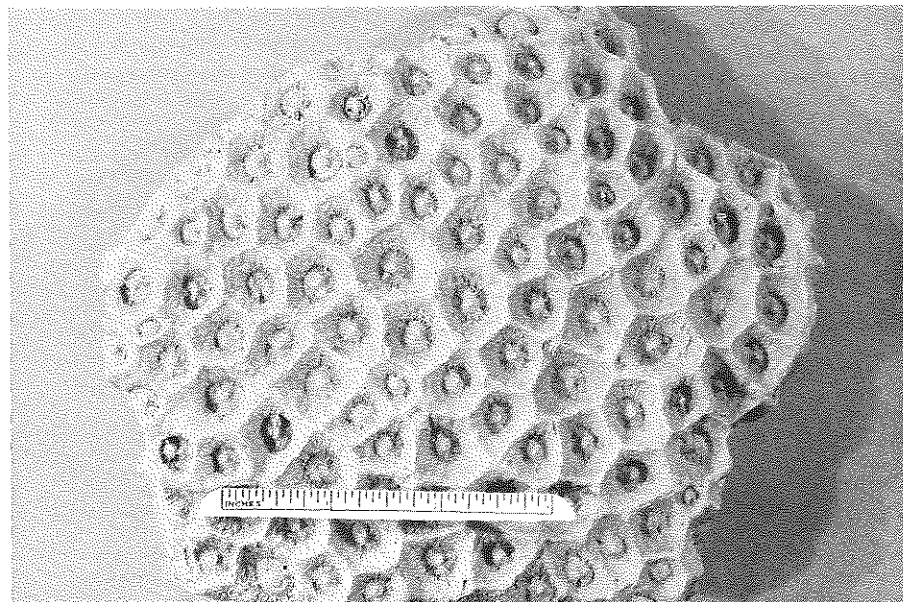


A. Cluster of *marcasite* crystals common in the strip mines of Marion and Mahaska Counties.

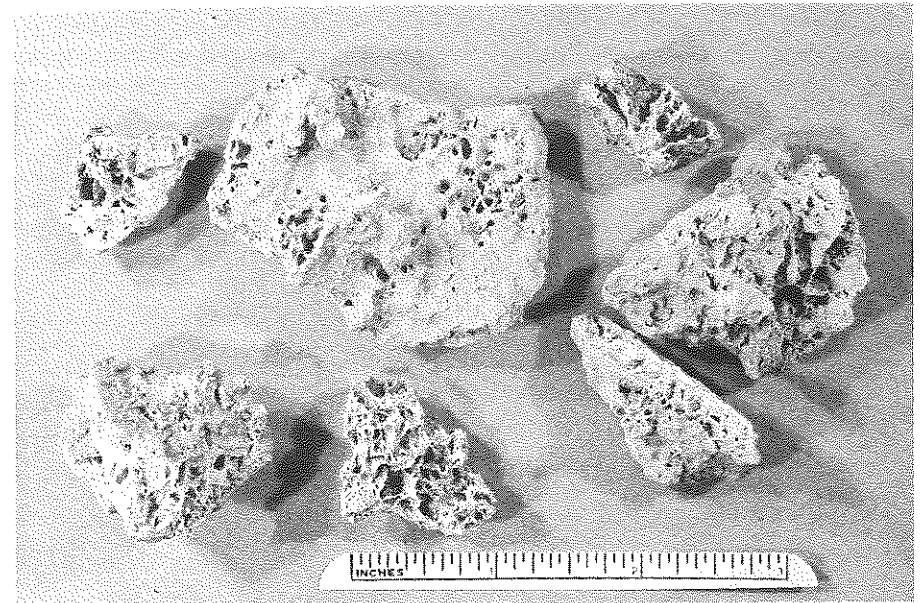


B. Close-up of plant material in interior of coal ball. X 1.2

C. *Lithostrotion* specimen in the collection of the Iowa Geological Survey. The fossil is completely silicified.



D. Small fragments of *smithsonite* "drybone" ore from the old Ewing diggings near Durango.



2. In the floor of the Des Moines River and its tributary valleys from Keosauqua downstream to Farmington when the water level is low enough. Check the beds of Copperas Creek two miles northwest of Bentonsport, Bear Creek across the river about a mile south of Bentonsport, and Indian Creek west of Farmington.
3. In a quarry along Lamalees Creek on the Walt Self farm north of Sandusky in the NW $\frac{1}{4}$ sec. 36, T. 66N., R. 5W., Lee County. Check also the slopes and bottoms of ravines emptying into the creek for as far as a mile upstream from the quarry.
4. A steep (and dangerous) roadcut through the Mississippi River bluff leading to the Iowa Gateway (barge) Terminal along the north line NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 30, T. 66N., R. 4W., Lee County. Look near the lower part of this cut.
5. A private collecting location known as "Baltimore Hills" adjacent to Geode State Park approximately five miles south of New London. A fee is charged to collect here.

Another excellent collecting area is a privately owned strip mine just across the Des Moines River from Iowa near St. Francisville, Missouri. Here too, a fee is charged.

Some of the Warsaw Formation geodes contain tiny, beautifully clear, glassy *quartz* prisms that are doubly terminated, that is, they have pyramidal points on both ends (plate 13D). These are similar to, but much smaller than, the so-called "Herkimer diamonds" found near Little Falls, New York. The largest crystals observed are no more than one-eighth inch in diameter and one-half inch long.

Small geodes filled with well developed *quartz* crystals can be collected from an exposure of the Aplington Dolomite one mile east of Chapin, on the east side of Highway 65 and just north of the county road in the NW corner sec. 34, T. 93N., R. 20W., Franklin County. The geode-bearing zone also occurs in the quarries about a mile west of Chapin and at the south edge of Sheffield, on both sides of Highway 65 south of Bailey's Creek. At the latter site some of the geodes contain white and yellow botryoidal *chalcedony* and some are completely filled. Another location is in an abandoned quarry half a mile north of the town of Aplington in Butler County. A quarry 2 $\frac{1}{2}$ miles north of Roland in southeastern Hamilton County has reportedly yielded good spherical *quartz* geodes from the Osage Series. However, this quarry was inoperative and filled with water when visited recently.

A botryoidal *chalcedony* showing beautiful red, orange, white and gray wavy banding on beveled edges can be seen in geodic cavities in the lower Keokuk limestone and chert in quarries near Keswick, Ollie and Harper in Keokuk County (plates 15E and 15F). Weathered surfaces of the *chalcedony* range from faint yellow to brilliant orange-red. Black *pyrolusite* dendrites may be spread across fracture faces and provide an interesting mottling, while clear, sparkling *quartz* druses or larger *quartz* crystals may be found in the interior of the cavities. Some of these geodes are as much as 12-18 inches in diameter. *Millerite* may also be found in some of these cavities and tiny *pyrite* and *goethite* crystals commonly are scattered on the *quartz*. Amateur collectors call this rock "coldwater agate" after a somewhat similar rock in Wisconsin limestones. Good specimens are much sought after. In fact, the "coldwater agate" geodes of Keokuk County have become rather famous as gemstone material across the country (plates 13A and 13B).

Another "coldwater agate" can be found in geodic cavities and *chert* nodules in the Rapid Member of the Cedar Valley Formation along the bluffs of the Cedar River in northeastern Benton County. The Benton County agate, which lacks the spectacular red-orange hues found in the Keokuk County agate, consists mainly of alternating bands of gray and white *chalcedony* lining the inside of geodic cavities, with gray botryoidal *chalcedony* or crystalline *quartz* partly or completely filling the interior (plate 12B). These *chalcedony*-filled geodes are found at the contact of the glacial drift and Cedar Valley Limestone, but the *chalcedony* is in place in the limestone or in *chert* nodules that weather out of the carbonate matrix. Take a sturdy shovel and clawed digging tool when hunting for this agate. It may be necessary to go through two feet of drift in some places along the valley slope to reach the bedrock. Two locations where this agate can be found are on the Snyderock farm in the NE $\frac{1}{4}$ sec. 8, T. 85N., R. 9W., and in the quarry in the river bluff in the NE $\frac{1}{4}$ sec. 11, T. 85N., R. 9W., about two miles south of Urbana. Any limestone quarry, roadcut or natural exposure in the Cedar Valley Formation in this area is a likely collecting site for the agate-bearing geodes. They are reported to have been found near Shellsburg and Walker and in Black Hawk and Bremer Counties.

Still another type of geode agate can be found along stream beds in the Manchester and Delhi areas of Delaware County. This is generally a rough *chalcedony* with cavities partly or completely filled with *quartz*. Apparently they are fossil replacements that have weathered out of the bedrock. The banding is similar to the Benton County agate.

Lake Superior *banded agates* and *red jaspers* suitable for ornamental jewelry can be collected from the Mississippi River gravels at New Albin, Harpers Ferry, Bellevue, Sabula, Almont, Muscatine and Burlington, and along the Little Sioux River in northwestern Iowa, as well as in practically any of the numerous gravel pits and sandbars scattered across Iowa. Fortification banding patterns in brownish-red and white are most common (plate 12D). The sand and gravel bars along the Little Cedar River in northeastern Floyd County provide moderately good agate hunting. The Lake Superior agates comprise the commonest and best known gemstone in Iowa.

Carnelian agates, a clear red *chalcedony* of pale to deep shades, and usually not banded like the Lake Superior agates, can be found in the Des Moines River gravels from Des Moines downstream and in the gravel pit on the west side of the Skunk River near Rome. Cloudy "Montana" type agates and moss agates also have been collected in Iowa gravel deposits, but are not as common.

Another fine gem material that can be found in Iowa gravels is *silicified (chertified) wood*. This usually is black, brown or gray with streaks of white. The author has collected small fragments from the gravel pits north of Sabula, while good specimens reportedly have been found near Emmetsburg and Graettinger in Palo Alto County. Silicified wood containing small smoky *quartz* crystals has been collected from coal mine dumps in the Wilcox Wildlife Preserve in southeastern Marion County. The black coloring may be from impure carbon included in the *quartz*. Elsewhere in this vicinity *quartz* crystals have been found with included *goethite* needles. *Quartz* does not seem to be abundant in the coal strip mines.

Chert of various colors, commonly weathering brown, is abundant in all gravel deposits. The limestone and dolomite strata of eastern Iowa contain much white, gray and brown *chert*. Some of these *cherts* can be cut and polished for gemstone use. Nodules of black *chert* speckled with small embedded white fusulinid fossils occur in the Plattsmouth Limestone of Pennsylvanian age in quarries near Grant and Stennet in Montgomery County (plates 12A and 12C). This *chert*, which is polishable, has been called "protozoa agate" or "rice agate" by amateur collectors. A strikingly banded light and dark gray *chert* with occasional red bands is present in exposures of the St. Louis Formation of Mississippian age near Humboldt and in the quarries west and south of Mt. Pleasant in Henry County. The Mt. Pleasant quarries and the beds of Big Creek in southern Henry County and Cedar Creek in Jefferson and Henry Counties also yield the silicified colonial coral *Lithostrotion* (plate 11C), often streaked with red and orange by iron oxide, that can be sawed and polished, revealing unique patterns.

Rough masses of *chalcedony* are fairly common in gravel deposits. One of the pleasant surprises of the mineral collector is to saw these *chalcedony* masses in two and find the interior to be a beautiful *banded agate* that takes a very high polish. Botryoidal *chalcedony* also is common as the inner lining of geodes, while the geode shells themselves consist mainly of *chalcedonic quartz*.

The St. Peter Sandstone of northeastern Iowa, which is nearly pure *quartz* in some localities, is used in the manufacture of glass and for various other purposes including abrasives, filters, fluxes, engine sand and molding sand. The Clayton Silica Company mine along the Mississippi River at Clayton is one of Iowa's biggest producers of high-quality *quartz* sand. Sand and gravel deposits are used extensively for building and paving purposes. *Quartz* crystals, *agates*, *jaspers* and *chalcedony* are used widely for jewelry and ornamental stones. The *quartz* geodes of southeastern Iowa have been prized collector's items for many years. *Chert* and *flint* were the stones which prehistoric man and Indians used for cutting and scraping tools, arrowheads and spearpoints. *Chert* and *flint* also were valued for the sparks they gave when struck together for starting fires. These Indian artifacts can be found in many Iowa farm fields and woodlands, especially along river bluffs and terrace levels which were preferred for campsites or burial grounds.

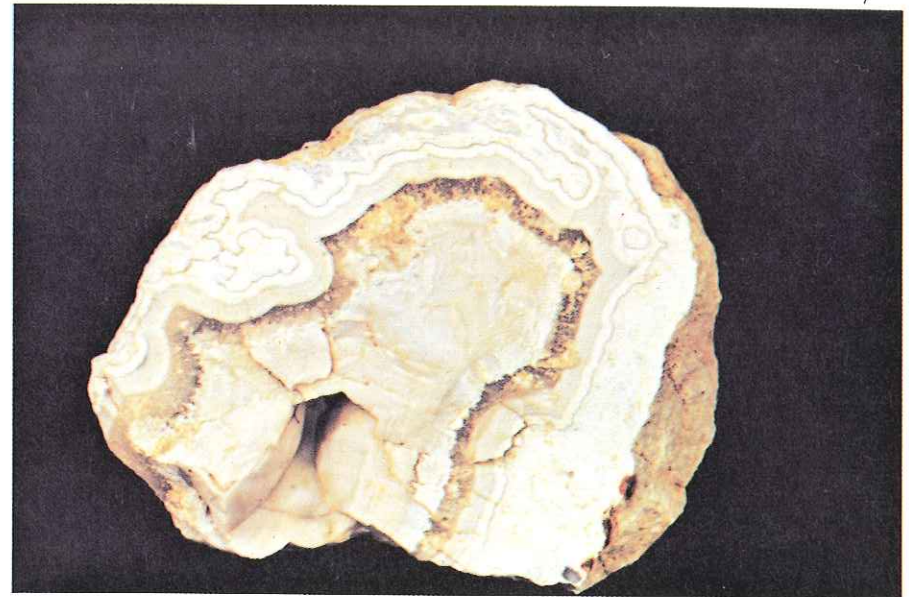
RADIOACTIVE MINERALS

In 1953 a landowner and amateur prospector suspected the presence of radioactivity in a rock formation on his property south of Knoxville. Subsequently, a geologist from the Iowa Geological Survey working near the community of Columbia, about nine miles south of Knoxville in Marion County, found radioactivity in some scattered, dark, fist-sized nodules. The nodules, found in a field, were weathering out of a shale formation belonging to the Des Moines Series of Pennsylvanian age. Chemical analyses indicated that the elements uranium and thorium were present and that the percent uranium was close to commercial grade ore. For a time, newspapers around the state gave this story a great play, hinting at the presence of commercial uranium deposits in Marion County and perhaps elsewhere in Iowa. Unfortunately, these radioactive nodules have never been found in sufficient concentration for commercial recovery.

Although the radioactivity of these nodules is known to come from the elements uranium and thorium, the specific mineral in which they occur has not been identified. Chemical analyses showed the radioactivity is associated with detrital heavy minerals that are mostly *apatite*. A geiger counter or scintillometer is needed to measure the radioactivity.

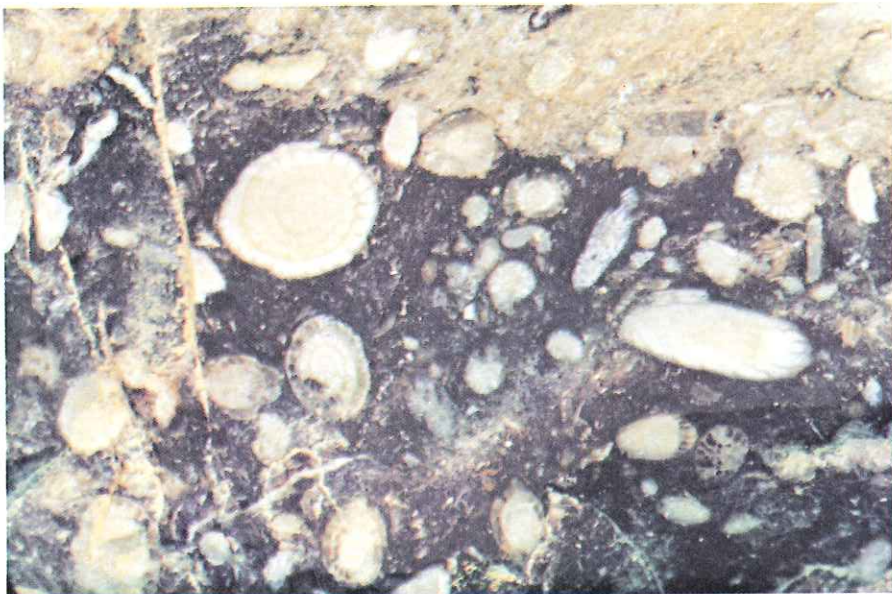


A. Black *chert* with embedded white *fusulinid* fossils. Plattsmouth Limestone, Montgomery County. X 1.1

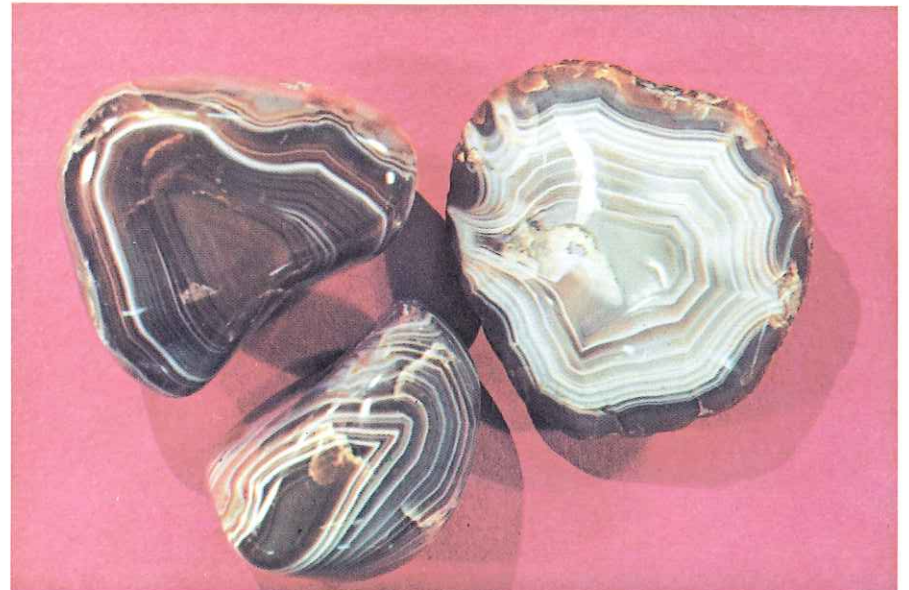


B. Nodule of "coldwater agate" from Benton County with bands of gray and white *chalcidony* and crystalline *quartz*. X 1.6

C. Close-up of *fusulinids* in Plattsmouth Chert. X 4.0



D. Lake Superior agates with fortification banding. From Mississippi River gravels. X 1.0





A. Polished cabachon made from "coldwater agate" material of Keokuk County. X 1.5.



B. Another variation of "coldwater agate" from Keokuk County that is popular for cabbing.

C. Quartz geode from near Sandusky, Lee County. Scale in inches.



D. Doubly terminated quartz crystals found in geodes in the Warsaw Formation, Lee County. X 2.0



Following the Marion County discovery another uranium "find" was reported from the old lead mining area of Dubuque in 1958. Evidently this was just another small and isolated radioactive deposit, because no attempts were ever made to develop it. Other discoveries of radioactive rocks in Iowa probably will turn up in the future, but the chances of finding commercial deposits are extremely doubtful based on the Geological Survey's examination of hundreds of shale samples throughout Iowa. Still, the possibility of an unusual discovery is not discounted by geologists.

SIDERITE (iron carbonate FeCO_3)

Siderite is a yellowish-brown, light to dark brown and grayish-yellow mineral that crystallizes in the hexagonal system as rhombohedrons with curved faces resembling dolomite. It tarnishes darker reddish-brown to blackish-brown and may display iridescent surfaces. Commonly it is granular or occurs in cleavable masses. It also may occur in botryoidal, compact and earthy forms. The luster is glassy, pearly or dull. The streak is white or pale yellow. It ranges from translucent to opaque. *Siderite* reacts slowly in cold hydrochloric acid, but dissolves with brisk bubbly activity in hot acid. The hardness is 3.7 to 4.2 and the Sp.G. 3.96 when pure, decreasing when manganese, magnesium and calcium substitute for iron. When heated, *siderite* blackens and becomes magnetic.

Siderite is reported to be rather common in the coal mining region of southern Iowa as massive, fine-grained *clay ironstone* nodules in shales and coal beds, notably in Mahaska and Marion Counties. This is the only type of *siderite* the author has seen in Iowa. It is not to be confused with *pyrite* or *marcasite* which have a characteristic yellow metallic luster, with brown crystalline *calcite* filling veins in septarian concretions, or with massive *sphalerite* which gives off a hydrogen sulfide odor in hydrochloric acid. *Pyrite*, *limonite*, *calcite* and *quartz* are common associated minerals. Some of the *siderite* concretions from the strip mines have fossil plant remains in the interior that are similar to the famous Mazon Creek-Braidwood specimens of Illinois.

Siderite clay ironstone concretions also can be picked up at most gravel pits or from the glacial drift in Iowa. They typically weather in yellows, browns and blacks forming *limonite* and *goethite*, and are pale to dark yellowish-brown on fresh surfaces. They are quite dense and heavy. The shales and sandstones of Cretaceous age exposed along the Big Sioux River valley in Woodbury, Plymouth and Sioux Counties are another source of small clay ironstone *siderite* concretions.

This mineral, although widespread in United States, is the least important of the iron ores.

SMITHSONITE (zinc carbonate ZnCO_3)

Smithsonite is a secondary mineral altered from *sphalerite* by oxidation of the sulfide above the water table and by action of percolating ground water. Because it often has a porous or honeycomb structure resembling dried bones, miners call it *drybone ore* or simply *drybone* (plate 11D). It crystallizes in the hexagonal system, occurring in rhombohedral crystals with curved faces, but good crystals are rare. It usually is found as cellular, porous, bone-like and finely crystalline masses. It also occurs as botryoidal coatings, crystalline incrustations, stalactites, coarse granular and compact masses, as veinlets in limestone and dolomite and as pseudomorphs after *calcite* crystals. The mineral commonly is stained yellowish-brown by *limonite*, but on fresh surfaces the color ranges from white to light gray and tan. It may also be green, blue or brown. It is translucent. The luster is glassy to dull. The streak is white. *Smithsonite* bubbles in cold hydrochloric acid. It has a hardness of 4 to 4.5 and is fairly heavy for a carbonate. The Sp.G. is 4.43 when pure, but ranges between 4 and 4.45.

The zinc carbonate deposits found in Iowa occur in crevices and bedding plane openings in limestones and dolomites in the lower part of the Galena Formation near Durango and Dubuque. Dumps of the old mine workings such as the west extension of the Lockey Drybone Mine at the foot of the valley slope on the west side of Catfish Creek in the SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 33, T. 89N., R. 2E., have yielded small pieces of drybone ore. Unfortunately, these old mine dumps are now mostly overgrown. The old Ewing diggings along the south bluff of the Middle Fork, Little Maquoketa River, in the SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 36, T. 90N., R. 1E. are a fairly good collecting location. *Smithsonite* drybone is abundant in the dolomite forming the walls of the diggings. Be careful in this vicinity as there are some abandoned and unfenced vertical mine shafts posing serious danger to any unsuspecting collector. The Ewing diggings, which were worked by the Indians before 1790, mark some of the oldest mines of the district. They were operated by Julien Dubuque as the "Mines of the Maquoketones" (a variation of Maquoketa which in Indian meant *bear*) and by miners from eastern United States beginning about 1821.

Smithsonite also has been reported rarely on weathered *sphalerite* crystals in the Warsaw Formation geodes as bluish-gray or greenish-yellow botryoidal crystals and as white crusts on the *sphalerite*.

Despite widespread occurrence, *smithsonite* is relatively unimportant in the United States as an ore of zinc. Oxidized zinc ore does not yield high-grade concentrates with good recovery of the metal. Since 1930 only very small quantities have been mined in the Upper Mississippi Valley district. *Sphalerite* is the main ore mineral of zinc. *Smithsonite* is now regarded only as potential future reserves.

SPHALERITE (zinc sulfide ZnS)

Sphalerite or *zinc blende* occurs in crystals and compact, cleavable masses. Crystallization is isometric. Cleavage is good in six directions and the mineral splits into tetrahedral (4 faces) and dodecahedral (12 faces) crystals. This mineral nearly always contains iron (maximum content 26 percent). Colors usually are yellow, brown or black, and less often red, green and gray. The deep brown or black variety is called *black jack* by miners (plate 14A). Pure varieties, which are almost colorless and transparent, are rare. The streak is brownish to light yellow and white. The luster is resinous or adamantine. *Sphalerite* may be mistaken for *galena* with which it is frequently associated. This deceptive appearance has resulted in the names *mock-lead* and *false-galena*. The mineral is brittle and shows a conchoidal fracture. The hardness is 3.5 to 4 and the Sp.G. is 3.9 to 4.1. *Sphalerite* dissolves in hydrochloric acid, giving off a strong "rotten egg" odor of hydrogen sulfide gas.

Sphalerite can be found as small, dark, cleavable masses that are scattered widely through limestones and dolomites ranging from Mississippian to Ordovician age in the eastern half of the state. The heaviest concentrations are in the lower Galena and upper Decorah Formations in the lead-zinc district around Dubuque. In this district zinc sulfide has been mined from fillings along inclined veins and faults and horizontal bedding planes called pitches and flats. *Sphalerite* usually is not found in natural rock exposures above the water-table level because oxidation will have altered the mineral to *smithsonite*. Small cleavage pieces of *sphalerite* can still be found in the dumps of the old mine shafts such as at the Beadle Mine in the SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 33, T. 89N., R. 2E., along Palmer's Creek, a tributary of the South Fork, Catfish Creek; at the Bonson Mine in the SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 6, T. 89N., R. 2E., about three-quarters of a mile south of Durango on the east side of the South Fork, Little

Maquoketa River; and at the Sherrill Mound district mines in the central part of the E $\frac{1}{2}$ sec. 15, T. 90N., R. 1E., on the east side of Haberkorn Creek; and in the NW $\frac{1}{4}$ sec. 21, T. 90N., R. 2E., along the North Fork, Little Maquoketa River. New and deeper quarrying operations in the lower Galena-upper Decorah section in the Dubuque vicinity would seem to be a good place to check for both *sphalerite* and *galena*.

One of the better collecting sites for *sphalerite* outside of the Dubuque district is the Wendling limestone quarry about a mile west of Moscow. This quarry is located on the west side of the Cedar River in the SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 8, T. 78N., R. 2W., Muscatine County. The sulfide is found as thin, dark partings along bedding planes and as small, amber-colored crystals with *calcite* in the Spring Grove Member of the Wapsipinicon Formation that is being excavated below the water table in the deepest part of the quarry. Good samples can be found in the rubble piles on the lower level of the quarry floor. Small cleavage masses of black, resinous *sphalerite* implanted on *calcite* have been collected from the Coralville quarry in Johnson County; from a quarry in sec. 35, T. 78N., R. 16W., Poweshiek County; and from Pint's quarry near Raymond. The quarry northeast of Ollie in Keokuk County yields scattered pieces of black, resinous *sphalerite* on botryoidal *chalcedony*. Black crystals and cleavable masses of *sphalerite* up to three inches in length also may be found on *quartz* crystals or botryoidal *chalcedony* in the Warsaw Shale geodes of southeastern Iowa.

Zinc is one of the four metals produced and used in greatest quantity by industrialized nations. In the United States it ranks behind steel, aluminum and copper in tonnage of metals produced and consumed. Large quantities are imported from Canada and Mexico. *Sphalerite* is the most important ore of zinc. The largest use of zinc is as a coating to protect steel products from corrosion (galvanizing). Such steel products as roofing, siding, structural steel, outdoor wiring, ship hulls, steel piers, pipes and storage tanks are all galvanized with zinc. Other large uses of zinc are as an alloy in die-casting automobile parts, electric appliances, tools building hardware, toys and business machines. Additional uses are in making brass of which about 30 percent is zinc, and in paints, pigments and chemicals.

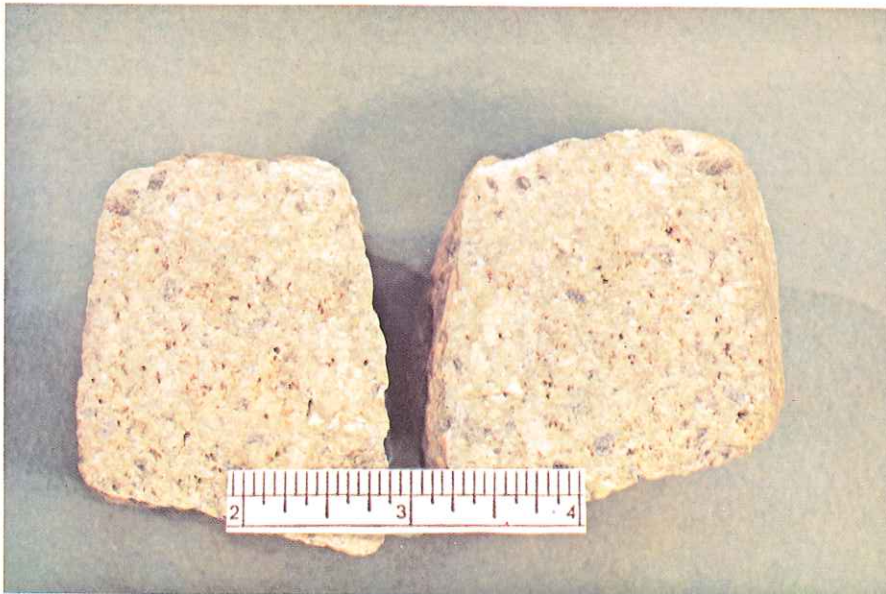


A. Cleavage fragments of black *sphalerite* showing resinous luster. Dubuque area. X 1.1



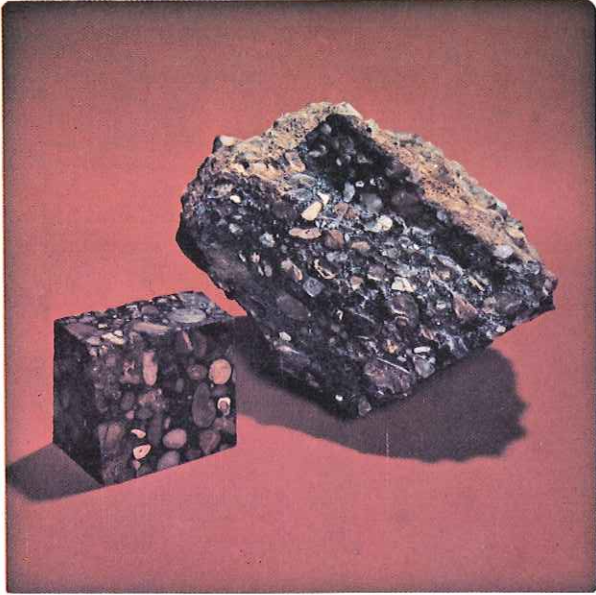
B. Polished stones from gravel pits. X 0.75

C. *Epidosite* rock with characteristic pistachio green color. Includes much *feldspar*. Scale in inches.



D. *Zeolite* minerals filling the cavities of basalt rock. Found in Mississippi River gravels.

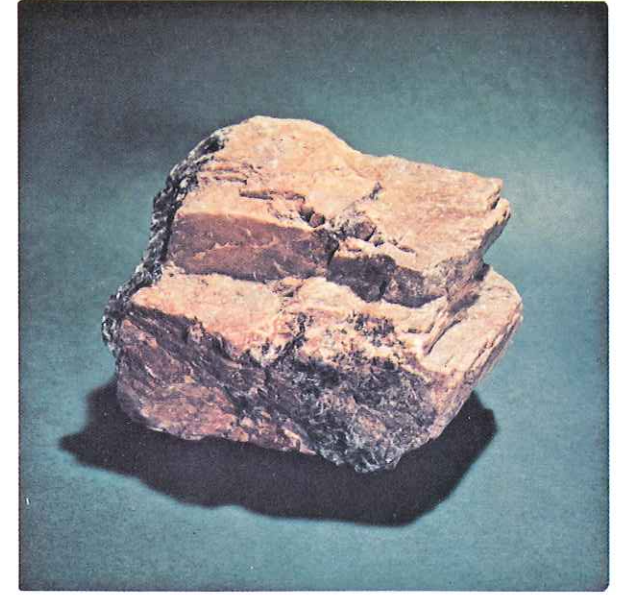




A. *Limonite* cemented "peanut conglomerate" from the Cretaceous of Guthrie County. Rough and sawed specimens. X 0.40

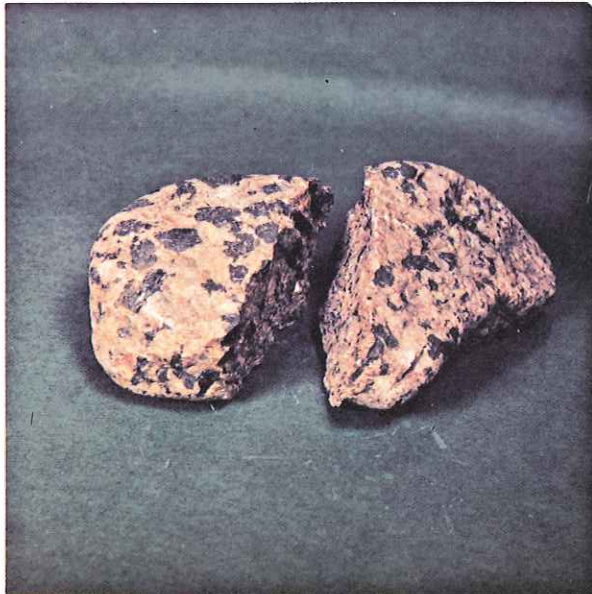


B. Coal ball containing *marcasite*, *calcite* and plant material. Mahaska County. X 0.25

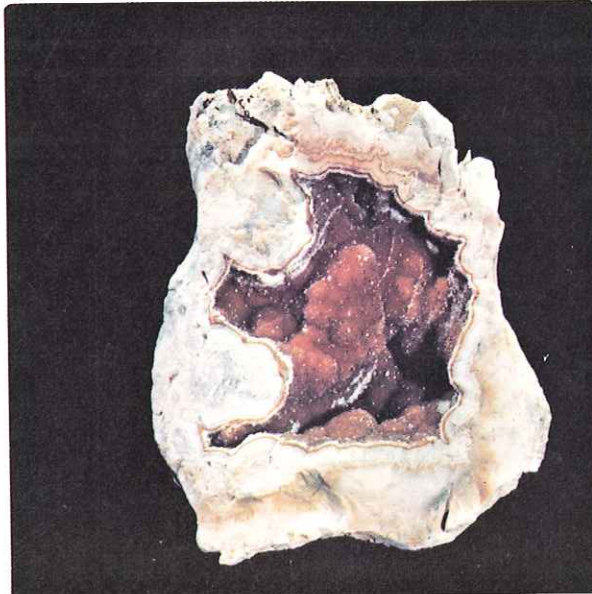


C. Blocky cleavage fragment of flesh-pink *orthoclase* found in gravel pit near Cherokee. X 0.35

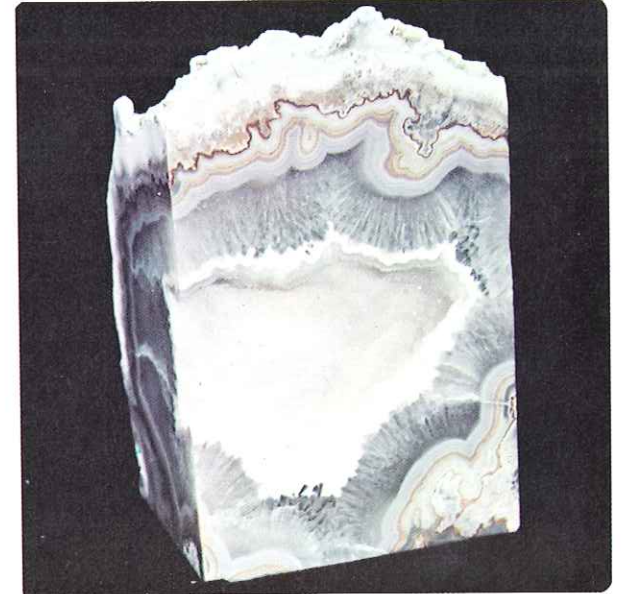
D. Igneous rock, probably syenite, with large black *hornblende* crystals. Found in gravel pit near Hawardan. X 0.40



E. "Coldwater agate" geode from Keswick area. Red drusy *quartz* in interior surrounded by banded *chalcedony*. X 0.20



F. Sectioned "coldwater agate" geode from Keswick area. Snow-white crystalline *quartz* surrounded by banded *chalcedony*. X 0.25



CHAPTER VI

MINERALS FROM GRAVEL DEPOSITS AND DRIFT BOULDERS

Many different kinds of minerals and gemstones can be found in the rocks of the gravel pits and in boulders from the glacial drift (plate 14B). These sources provide some of the most prolific mineral grounds available in Iowa. Moreover, gravel deposits and glacial boulders are widespread in Iowa and afford the only good collecting in some sections, particularly in the western part of the state where bedrock exposures are limited. Of course, many of the minerals in the igneous and metamorphic rocks are so small and scattered they are impossible to identify without the aid of a microscope. Therefore, only the more common specimens that can be found as crystals and crystalline masses or grains that are large enough to be identified with the unaided eye or with a hand lens are described. These include *epidote*, the *feldspars*, *garnet*, *hornblende (amphibole)*, *mica*, *pyroxene* and the *zeolite* group. Advanced amateur collectors may be able to recognize other minerals. Not included here are the abundant microcrystalline varieties of *quartz* and minerals of sedimentary rocks which are described in Chapter V. A complete listing of minerals found in gravel pits is impractical for this work.

EPIDOTE (hydrous calcium aluminum iron silicate $\text{Ca}_2(\text{Al,Fe})_3(\text{SiO}_4)_3(\text{OH})$)

Epidote is a hard, green mineral common in metamorphic rocks like gneiss and schist, in metamorphosed limestones, altered igneous rocks, pegmatites, and in cavities and fissures in basalts. Crystals are monoclinic. It commonly occurs in prismatic, sometimes acicular, crystals that are elongated and rounded at one end. It also occurs in granular rock masses. *Quartz* and *feldspar* are common associates. *Epidote* forms by the hydrothermal alteration of other minerals such as *garnet*, *olivine (chrysolite)*, *hornblende*, *augite*, *biotite* and *plagioclase*.

The unique yellowish-green (pistachio) color of *epidote* is its most distinguishing property although this color may pass into lighter and darker shades of green. Other colors are yellowish-brown, light brown and black. The streak is uncolored to grayish. The luster is glassy but may be pearly on cleavage faces. The hardness is 6 to 7 and the Sp.G. 3.25 to 3.5. Cleavage is good in one direction parallel to the

basal pinacoid. Some of these prismatic faces may be striated longitudinally. The mineral is brittle and fractures unevenly. It is transparent to translucent.

The author has collected *epidote* at many gravel pits in Iowa as porous, granular, crystalline rock masses making up nearly all or part of a rock and as aggregates of tiny crystals filling the cavities of amygdaloidal basalts with *zeolites*. Masses of the fine, granular, crystalline form of *epidote* are called *epidosite* and usually contain much associated *feldspar*, *quartz* and *hornblende* (plate 14C). The peculiar yellowish-green color can be recognized easily. *Epidosite* rock is hard enough to be cut for ornamental use and polished as a low-grade gemstone. Break open a specimen and study the crystalline aggregates with a hand lens. The green and yellow-green glassy *epidote* is quite conspicuous.

The Mississippi River gravel deposits have an abundance of dark purplish-brown porous traprock called amygdaloidal basalt. Commonly the small holes (amygdules) in the basalt are filled with lighter-colored secondary minerals such as *epidote*, *calcite* and the *zeolites* (plate 14D).

FELDSPAR (aluminum silicates with potassium, sodium and calcium)

The *feldspars* are a group of nonmetallic minerals that are important in forming igneous and metamorphic rocks. Mineralogists estimate that 50 to 60 percent of all igneous rock is composed of *feldspar*. All *feldspars* are very similar in their chemical composition and physical properties. There are two basic subgroups, *alkali feldspars* and *sodium-calcium feldspars*.

Many Iowa materials producers have huge stockpiles of gravel in which good pieces of cleavable *feldspar* may be found. Sizeable cleavage fragments of light reddish-brown *orthoclase* were collected at the Shea Sand and Gravel Company pit two miles south of Cherokee (plate 15C), and from a gravel stockpile along the Cedar River about three miles east of Atalissa, and smaller fragments from the

Mississippi River gravel deposits near Sabula and Clinton. A red to pink porphyritic granite that is common in the Mississippi River gravels contains good phenocrysts of *orthoclase*. A mass of cleavable white *microcline* about the size of a tennis ball was collected from a gravel pit southwest of Lake City in the NW¼ sec. 23, T. 86N., R.34W., Calhoun County.

Although *plagioclase feldspars* are abundant in igneous and metamorphic rocks, they are harder to identify than the *alkali feldspars* because crystals are not common or are small.

ORTHOCLASE (alkali feldspar $K(AlSi_3O_8)$)

Orthoclase is found in individual crystals, twinned crystals, cleavable masses, and grains in igneous and metamorphic rocks such as granite, syenite and gneiss. The best crystals and mineral specimens generally are found in veins in granites and in porphyritic rocks. Crystallization is monoclinic with crystals often prismatic parallel to the basal pinacoid. Good crystals are rare in gravel deposits, but large cleavage fragments can be found with a bit of searching. The most characteristic color is a fleshy pink, although it may be colorless, white, yellow, or reddish-brown. The luster is glassy and the streak white. *Orthoclase* is brittle and has good cleavage in two directions, basal and pinacoid, at 90 degrees, giving a blocky shape. The fracture is uneven to conchoidal. The mineral has a hardness of 6. The Sp.G. is 2.56 to 2.59. *Orthoclase* is insoluble in acids.

MICROCLINE (alkali feldspar $K(AlSi_3O_8)$)

Microcline usually is found in granite pegmatite dikes. Crystals are triclinic, but little different than monoclinic *orthoclase*. *Microcline* may be white, creamy yellow, flesh pink, reddish-brown and green, depending upon impurities. It is the only green *feldspar*, a variety named *amazonstone* or *amazonite*. The luster, streak, cleavage, transparency, brittleness, hardness and Sp.G. of *microcline* are practically identical to *orthoclase*. However, thin, wavy, banded intergrowths of white *plagioclase feldspar (albite)* commonly run through *microcline*. This is known as perthitic texture and is distinctive of the mineral. It is seen clearly in the green and reddish-brown varieties.

PLAGIOCLASE (sodium-calcium feldspar ($Na(AlSi_3O_8)$ to $Ca(Al_2Si_2O_8)$)

The *plagioclase feldspars (albite, oligoclase, andesine, labradorite, bytownite* and

anorthite) are reported to be the most abundant rock-forming minerals. They are chiefly found in volcanic and igneous rocks such as monzonite, diorite and gabbro and in smaller quantities in granite, syenite and rhyolite. Crystallization is triclinic, but crystals are not common. Colors generally are gray or white but occasionally yellow, reddish, greenish and black from inclusions. There are two good cleavage directions, perfect basal and good pinacoid, making an angle of 93-94 degrees. Like the other *feldspars*, *plagioclase* has a glassy luster, a white streak and is transparent to translucent. It has the same brittle property and hardness of 6. The Sp.G. of the *plagioclase* members gradually increases from 2.62 in *albite* to 2.76 in *anorthite*. Thin parallel twinning striations on cleavage faces are common to most plagioclase specimens and diagnostic of this feldspar.

Feldspar finds its greatest use in the manufacture of glass and in the pottery industry. It is used in making enamels, porcelain, tile and other ceramic products, in scouring soaps and roofing granules. A number of *feldspar* varieties are used as gemstones, including the green *microcline* called *amazonstone*; the dark *plagioclase, labradorite*, with the opalescent reflection of blue and green colors; a white variety of *feldspar* with a microperthite texture of *orthoclase* and *albite*, called *moonstone*; clear glassy crystals of *oligoclase*; and white *oligoclase, orthoclase, microcline, albite* and *labradorite* containing tiny scales of *hematite* which reflect brilliantly and are called *sunstone* or *aventurine*.

GARNET (silicates of calcium, magnesium, iron, manganese, aluminum, chromium)

Garnet is a general name for a group of six minerals that have similar physical properties but differ somewhat in chemical composition. All *garnets* crystallize in the isometric system, commonly forming dodecahedrons and trapezohedrons or combinations of these forms. They are also found frequently in irregular embedded grains. Red is the dominant color of *garnet*. However, the several varieties of garnet occur in many different colors ranging from black and brown through orange, yellow, green, white, pink, cinnamon and purplish-red to deep vermilion. The luster is glassy. The hardness ranges from 6.5 to 7.5 and the Sp.G. from 3.5 to 4.3. *Garnet* has no cleavage. The mineral is brittle and the fracture is subconchoidal to uneven. The streak is white. *Garnet* is transparent to translucent. The chief varieties and their typical chemical formulas follow: *pyrope* ($Mg_3Al_2(SiO_4)_3$), *almandine* ($Fe_3Al_2(SiO_4)_3$), *spessartine* ($Mn_3Al_2(SiO_4)_3$), *grossular* ($Ca_3Al_2(SiO_4)_3$), *andradite* ($Ca_3Fe_2(SiO_4)_3$), and *uvarovite* ($Ca_3Cr_2(SiO_4)_3$).

Because *garnets* are often found in seed-like grains resembling pomegranate seeds

they have been called "seed stones". Seed-like *almandine* grains up to 1/8 inch in diameter of a deep purplish-red color and glassy luster have been observed in subpegmatite and metamorphic rocks in gravel pits at Lake View and Akron in northwestern Iowa, and at Shell Rock and Bellevue in northeastern Iowa. Generally the *garnets* are tiny and inconspicuous and a hand lens is needed to recognize them. A cobble of *biotite* gneiss seven inches in diameter picked up in a gravel pit south of Lake View was shot with irregular clusters of pink *almandine* grains embedded in the gneiss. Some of the *garnet* clusters measured 1/4 inch across or larger, giving the rock a slight pinkish cast.

HORNBLENDE (complex silicate $\text{CaNa}(\text{Mg,Fe})_4(\text{Al,Fe,Ti})_3\text{Si}_6\text{O}_{22}(\text{O}_1\text{OH}_2)$)

Hornblende (amphibole) is common in metamorphic and igneous rocks such as gneiss, schist, granite, syenite and diorite. As the above chemical formula indicates, hornblende is a complex silicate with a variable composition. Crystallization is monoclinic. Crystals commonly occur as short prisms with six sides appearing wedge-like in cross section. The mineral also is found in massive aggregates of interlocking crystals in columnar, fibrous and bladed forms. The color varies from dark green and dark brown to black. The luster is glassy and the streak generally uncolored or white. Cleavage is prismatic and highly perfect at 54 and 126 degrees. *Hornblende* is translucent on splinter edges. The hardness is 5 to 6 and the Sp.G. 2.9 to 3.4. This mineral yields water when heated in a closed glass tube.

Hornblende crystals up to an inch long were seen in a specimen of syenite collected from the L.G. Everist, Inc., gravel pit in the Big Sioux River valley one mile north of Hawarden in Sioux County (plate 15D). Crystals this size are hard to find, but every gravel pit is a potential source. *Hornblende* generally is easier to find and identify and occurs in larger crystals than *pyroxene* which it resembles. It has no economic value. *Feldspars, quartz, pyroxene, chlorite, calcite* and *epidote* are common associated minerals.

MICA (hydrous potassium aluminum silicate with iron and magnesium)

There are several micas, but only *muscovite* and *biotite*, which are the most important in forming rocks, are described here. All micas belong in the monoclinic system, occurring as six-sided plates. Their most prominent characteristic is their perfect basal cleavage, yielding thin, flat, flexible, elastic sheets (micaceous cleavage). *Mica* is soft and creases or bends easily under pressure; however, it cannot be scratched.

MUSCOVITE (potassium mica $\text{KAl}(\text{AlSi}_3\text{O}_{10}) (\text{OH})_2$)

Other names for *muscovite* are *common mica, white mica, potash mica* and *isinglass*. *Muscovite* is common as small crystals or masses in granite, gneiss and *mica* schist and as tiny flakes in sandstones and shales. The best and largest crystals are in pegmatites. *Muscovite* usually is colorless to gray but may be amber, light brown, green or rose. The luster is glassy to pearly and the streak white. It is transparent to translucent. Through a cleavage face it usually is pearly and opaque. *Muscovite* has a hardness of 2.5 to 3 and a Sp.G. of 2.76 to 3. This mineral is very tough and can stand great heat without melting.

BIOTITE (magnesium-iron mica $\text{K}(\text{Mg,Fe})_3(\text{AlSi}_3\text{O}_{10}) (\text{OH})_2$)

Biotite or *black mica* is darker than *muscovite* because it contains small amounts of iron and magnesium. *Biotite* has the same hexagonal, monoclinic crystallization as *muscovite*. Although not as abundant as *muscovite*, it is common in igneous and metamorphic rocks and pegmatites. It usually is black, brownish black, greenish black and may be tinged light yellow. The luster is vitreous and the streak white. It is usually translucent to opaque. The hardness is 2.5 to 3 and the Sp.G. 2.8 to 3.3.

In Iowa both *muscovite* and *biotite* are abundant in igneous and metamorphic boulders and cobbles in the glacial drift and in gravel pits. Most of the *mica* occurs as tiny, thin flakes or "books" set among larger and more numerous *orthoclase* and *quartz* crystals. Some granites have yielded nearly perfect *mica* crystals up to a quarter of an inch in diameter. A few sandstones, siltstones and shales in the Cretaceous and Pennsylvanian rocks have an abundance of tiny *mica* flakes that sparkle in the sunlight.

Outside Iowa, the largest *mica* crystals are found in pegmatites in the Black Hills, South Dakota, in Colorado, North Carolina, New Hampshire, Connecticut, Maine and Ontario, Canada.

Mica is important in the electronic and electrical industries for insulation. Poorer grades of mica are ground into flakes and powder and used in roofing materials, in wallboard, in paints, in rubber tires and as Christmas tree "snow."

PYROXENE (silicates of calcium and magnesium with iron, manganese, aluminum, sodium, etc.)

The *pyroxenes* are another important rock-forming group of minerals found in igneous and metamorphic rocks. They closely resemble *hornblende* from which they are hard to distinguish. Chemically, the *pyroxenes* have a composition like the *amphiboles*, although they are not as complex and are water-free. Most *pyroxenes* are monoclinic. *Enstatite* and *hypersthene* are orthorhombic. Only *diopside* and *augite* commonly form good crystals. The crystals usually occur as short four- and eight-sided prisms with square cross sections due to the near right-angle cleavage. *Pyroxenes* also may show a parting or pseudocleavage parallel to the base, i.e., at right angles to the prism faces. Typically the *pyroxenes* are shades of dark green, although they may be black, brown, gray and white. Only the most widespread *pyroxene*, *augite*, is described here.

AUGITE (Ca(Mg,Fe,Al) (Si,Al)₂O₆)

Augite crystallizes in the monoclinic system. It occurs in small crystals and crystalline masses. It is very common in the darker igneous rocks that are low in silica (*quartz*) and high in iron such as gabbro, dolerite and basalt, and as phenocrysts (enlarged crystals) in porphyrys. It also is found in gneiss and schist. *Augite* is found more often in granular masses than as well-formed crystals. The best and largest crystals are found in porphyrys. They usually form short, stout prisms with pyramids on both ends or they may be tabular. *Augite* is black or dark green with a glassy luster. The fracture is uneven. The hardness is 5 to 6 and the Sp.G. 3.2 to 3.4. The streak is white to gray to grayish-green. *Augite* is translucent on thin edges to opaque.

It is generally rather difficult to distinguish *augite* from *hornblende* when the crystals are small. However, if you can observe a good right-angle cleavage with your hand lens on some of the larger grains that are broken across their length, you should have a *pyroxene*.

ZEOLITES (hydrous silicates of aluminum with sodium, calcium and potassium, etc.)

The *zeolites* are a large group of closely related secondary minerals (approximately 27 have been identified) found in dark, fine-grained igneous rocks (traprock) formed from lava flows such as basalt and diabase. Occasionally they are found in granite and gneiss. They are formed by reaction of water on *feldspar* and *feldspathoids*, dissolving the sodium, calcium, potassium, aluminum and silicate from the basalt and depositing the new minerals from solution in the cavities, cracks and veins. *Zeolites* are colorless or white when pure, and colored pink, tan or gray by iron oxides or other foreign mineral matter. Crystals generally are fibrous, bladed and nearly equally developed in every direction (equant). The luster of the crystals is glassy and may be pearly on cleavage surfaces. The hardness ranges from 3.5 to 5.5. The Sp.G. ranges between 2 and 2.4. When heated, *zeolites* give off water continuously without change of crystal structure. However, if the temperature is raised high enough, the mineral will fuse, usually with bubbling and curling (intumescence). The dehydrated crystals can re-absorb most of the lost water when cooled. Many of the *zeolites* decompose or gelatinize in hydrochloric acid. Some of the more common *zeolites* are *heulandite*, *stilbite*, *chabazite*, *natrolite*, *analcite* and *thompsonite*. A number of other nonzeolite minerals frequently are associated with the *zeolites* in the traprock cavities. Included in this group are *prehnite*, *datolite*, *calcite*, *apophyllite*, *pectrolite*, *quartz*, *native copper*, *epidote* and *chlorite*.

Plate 14D shows *zeolites* and other minerals filling the vesicles of the dark purplish-brown basalt that is widespread in the gravel pits of the Mississippi River valley. This rock is thought to have originated in the Lake Superior region, probably in the *copper* district of the Keweenaw Peninsula, and was carried south by the glaciers. The color of the *zeolites* in this specimen ranges from colorless through milky white, yellow, yellow-brown, pink, and shades of yellow-green and green to black. *Epidote*, *chlorite*, *datolite*, *apophyllite* and *prehnite* may be represented in some or all of the green minerals. No attempt has been made to classify the *zeolites* found in the traprock of Iowa gravel pits although it would appear that reddish *analcite* is present and perhaps *natrolite* and *thompsonite*.

CHAPTER VII

OTHER MINERALS REPORTED IN IOWA

A number of other minerals reportedly have been collected in Iowa. These may be difficult to find and recognize because they are so scarce, occurring as widely dispersed masses and small crystals, or buried under a thick cover of soil, glacial clay, gravel and rock. In this group are included *apatite*, *copiapite*, (*quenstedtite*), *corundum* (sapphire), *diamond*, *epsomite*, *melanterite*, *silver*, *sulfur*, *turgite*, and *wurtzite*. There probably are several others on which information is poor or insufficient.

APATITE ($\text{Ca}_5(\text{PO}_4)_3(\text{F},\text{Cl},\text{OH})$)

A gray, nodular specimen of *apatite* was found in Wapello County. This can be seen in the State Historical Museum, Des Moines. South of Knoxville in Marion County, dark radioactive nodules weathering out of Pennsylvanian shales contain *apatite* as the main constituent of detrital heavy minerals. Extremely small crystals of clear to black *apatite* associated with *ankerite* and dolomitized, rhombohedral, brown *calcite* also were reported from a single vug in the septaria of the Oskaloosa-Knoxville area strip mines. *Apatite* is a common accessory mineral of metamorphic rocks, igneous rocks and pegmatites, and bedded phosphate deposits.

COPIAPITE (quenstedtite) ($\text{Fe}_4(\text{OH})_2(\text{SO}_4)_5 \cdot 18\text{H}_2\text{O}$)

A yellowish and dry material of the color of *sulfur* or slightly darker has been reported as incrustations of the lower part of overhanging ledges of sandstone of Pennsylvanian age near Montpelier in Scott County. This is thought to be *copiapite*. It is readily soluble in cold water. The hardness is 2.5 and the Sp.G. 2.2. It probably can be found on coal mine dumps where *pyrite* is oxidizing rapidly, but since it is water soluble it can be found only in protected spots.

CORUNDUM (Al_2O_3)

The shore of Lake Okoboji in Dickinson County reportedly yielded a pebble of blue sapphire in 1912 that was cut into a splendid gem of $1\frac{3}{8}$ carats. Little

significance is attached to this discovery, however, as it probably represents an isolated glacial pebble transported from Canada.

DIAMOND (C)

Diamond finds are rare in Iowa. Occasionally the Geological Survey receives an inquiry concerning rough stones of great hardness and greasy luster found in gravel deposits and suspected to be potential diamonds. Some years ago a gem quality green *diamond* about the size of a pea was found in gravel deposits at Dubuque and sold for a good price to a Chicago jeweler. *Diamond* discoveries seem to be more common in Michigan, Wisconsin and Indiana, indicating these states may be closer to the source rocks.

EPSOMITE ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$)

A thin surface coating or efflorescence of white *epsomite* has been reported under overhanging cliffs of limestone at the Starrs Cave exposure north of Burlington in the NW¼ sec. 19, T. 70N., R. 2W., Des Moines County. This mineral has a bitter taste and is highly soluble in water. *Epsomite* may be widespread in Iowa in sheltered places at limestone and dolomite exposures and quarries and on the walls of caves and limestone mines where rainfall and groundwater do not easily reach it.

MELANTERITE (copperas) ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$)

This mineral is found in small quantities as a white to green powdery encrustation on *pyrite* in shales, sandstones and coal deposits in the Pennsylvanian rocks. It is soluble in cold water and the powder may be easily washed off by rains only to reform within a few days. *Melanterite* also occurs on decomposed *pyrite* and *marcasite* in *sphalerite* ore in the Dubuque area. In some places it occurs as

tiny, white, needle-like crystals that may be confused with *halotrichite*. *Melanterite* has an astringent or metallic taste that puckers the mouth.

SILVER (Ag)

Small but measurable quantities of *silver* have been found alloyed with lead concentrates assayed for *silver* and *gold* from the old Lansing lead mine in Allamakee County and other mines in Wisconsin and Illinois. In some localities in the Upper Mississippi Valley district *silver* apparently occurs in *chalcopyrite*, *pyrite* and *marcasite*.

SULFUR (S)

Native sulfur, usually occurring as small powdery amorphous masses and occasionally as bright crystals, reportedly has been found along fractures or in small cavities in lead mines in northeastern Iowa. It is believed to have formed by decomposition of primary *pyrite* and *marcasite*. Small masses of bright yellow *sulfur* occasionally can be seen on weathered surfaces of Iowa coals.

TURGITE (hydrohematite approx. $2\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$)

A red powder of *turgite*, resembling *hematite*, may occur sparingly in the interior of some of the cavities in the limonitic iron ore at Waukon. It resembles *limonite* but has a red streak. It may have a botryoidal structure or be crimson in thin fibers.

WURTZITE (zinc sulfide ZnS)

This mineral is the hexagonal form of zinc sulfide. Like *sphalerite*, it usually contains iron and is brownish black. Crystals usually occur in pyramids or short prisms. Cleavage is distinct along one prism face. The luster is resinous and the streak brown. The hardness is 3.5 to 4 and the Sp.G. 3.9 to 4.1.

Wurtzite is a rarer and unstable form of zinc sulfide but it can crystallize from solution. It is stable above 1020°C however. It commonly is intergrown with *sphalerite* or *marcasite* and may alter to *sphalerite*. *Wurtzite* may be formed artificially by heating *sphalerite* above 1020°C and then cooling it.

A few crystals of *wurtzite* reportedly have been collected in Pint's quarry at

Raymond. Some *wurtzite* also may be present in the *sphalerite* deposits in the Upper Mississippi Valley district around Dubuque.

METEORITES

This book would not be complete without at least a brief reference to meteorites, the metallic and stony fragments that fall on the earth from outer space. Astronomers believe that some meteorites fall each year in practically every state. The fact that only a small number are found is because very few people would recognize one, especially the stony type, if they saw it lying in the field. Although meteorite finds are rare, amateur rockhounds and mineral collectors, because of their interest in stones, are as likely as anyone to discover them and are encouraged to send in specimens to the Iowa Geological Survey or to the United States National Museum Washington, D.C., for examination and identification. At least five meteorite falls known as the Marion (1847), Amana (1875), Estherville (1879), Forest City (1890) and Mapleton (1939) meteorites, and subsequent discovery of fragments, have been recorded in Iowa. In 1971 a stony meteorite weighing about 50 pounds was found in the SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 18, T. 77N., R. 5W., Johnson County. This specimen was identified and is currently being studied by Prof.'s J.H. Carman and G.R. McCormick of the University of Iowa.

Meteorite specimens from the Forest City, Estherville and Amana falls can be seen in the State Historical Museum, Des Moines, the University of Iowa Geology Department museum and Grinnell College, Grinnell. The Grinnell collection is by far the best in the state. A permanent display case inside the main south door of the science building holds 14 specimens.

There are three basic types of meteorites: iron (*siderites*), stony (*areolites*) and stony-iron (*siderolites*). The standard classification seems to be based on the amount of iron present in the meteorite, although each group has wide variations. Thus, an iron meteorite is one which is composed mainly of nickel-iron and its alloys; a stony meteorite is generally composed of silicate minerals such as *pyroxene*, *olivine* and *feldspar* and contains a minor, but varying amount of nickel-iron and sulfides; and a stony-iron meteorite contains about equal portions of metallic and stony material. The following excerpt was taken from the Oregon Department of Geology and Mineral Industries newsletter concerning meteorite recognition:

1. Meteorites are heavier than ordinary rocks. The Sp.G. ranges from about 3 for some stony varieties to about 8 for the iron; while most terrestrial rocks have a

Sp.G. well below 3. Meteorites are not porous or hollow, nor do they resemble cinders. The stony meteorites resemble terrestrial rocks and are often mistaken for them.

2. Meteorites are magnetic. The irons and stony irons are strongly attracted; the stony variety is only slightly attracted by a strong magnet.
3. Newly fallen meteorites usually have a black fusion coat and have shallow pits resembling thumb prints. Meteorites which have been exposed long to the weather may be brown or covered with rust, depending on the length of exposure.
4. On grinding a meteoritic specimen with an emery wheel, bright, shiny

nickel-iron alloy becomes visible. The nickel-iron ranges from tiny specks in stony meteorites to the entire mass in the irons.

5. Meteorites are irregular in form and may be almost any shape. A number of known meteorites are cone shaped, but none are as round as a ball.
6. All meteorites contain the element nickel. A test for nickel is usually best done by a scientist.
7. When the polished surface of an iron meteorite is treated or etched with dilute nitric acid, characteristic patterns known as *Widmanstatten figures* are formed. Terrestrial alloys do not form *Widmanstatten figures*. Etching is usually best done by a scientist.

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GLOSSARY

- Aggregate** A mass of mineral crystals or grains of one or more species. It may be loosely bound as a sediment or cemented tightly together. The particle size ranges from fine- to coarse-grained.
- Alteration** Any change in mineral composition of a rock or mineral caused by physical or chemical means; a secondary change in a rock or mineral.
- Amorphous** A mineral that has no crystalline structure, or whose internal arrangement is so irregular it lacks a characteristic external form.
- Amphibole** A group of dark, rock-forming ferromagnesian silicate minerals closely related in crystal form and composition and characterized by good prismatic cleavage parallel to the crystal faces and intersecting at angles of 56° and 124° . They are analogous to the *pyroxenes* but do not contain water and the cleavage angle is different.
- Amygdule** A small cavity formed by a gas bubble in an igneous rock and filled with secondary minerals such as *zeolites*, *calcite*, *quartz* or *epidote*.
- Amygdaloidal** Said of igneous rock containing numerous small cavities (amygdules) filled with secondary minerals.
- Andesite** A dark-colored, fine-grained volcanic (extrusive) rock consisting mostly of the *plagioclase andesine*, and one or more minerals low in silica such as *biotite*, *pyroxene* or *hornblende*.
- Atomic number** The number of positive charges on the nucleus of an atom; the number of protons in the nucleus.
- Atomic weight** Average relative weight of the atoms of an element referred to as an arbitrary standard of 16.0000 for the atomic weight of oxygen.
- Basalt** A dark- to medium-dark-colored, fine-grained, extrusive igneous rock composed primarily of calcium *plagioclase*, *pyroxene*, and with or without *olivine*. *Apatite* and *magnetite* are common accessories.
- Beneficiation** To improve the grade of ore by milling, sintering, etc.
- Bipyramid** Said of a mineral crystal with pyramids on both ends.
- Brecciated** A rock made up of angular, coarse fragments as distinguished from conglomerate which has rounded water-worn fragments.

- Cabachon** Rockhound term for a stone that has been cut and polished for jewelry such as a bola, bracelet or tie clasp.
- Cabbing** Making cabachons.
- Clinodome** The forms of the monoclinic system whose faces are parallel to the inclined axis, *a* while intersecting the other two axes.
- Concentric** Having a common center; said of layers of a mineral occurring in circles or spheres around another mineral.
- Concretion** A hard, compact, generally subspherical mass of mineral matter formed by precipitation from an aqueous solution often around a nucleus as a leaf, bone, or fossil shell in the pores of sedimentary or volcanic rock. Usually the composition is different from the rock in which it is found. Represents a concentration of some minor constituent such as silica, *calcite*, *dolomite*, *iron oxide*, *pyrite* or *gypsum*. Ranges from a small pellet to as much as 3 meters in diameter.
- Cone-in-cone** A sedimentary structure found in calcareous layers of shales and in the outer parts of large concretions, also in coals, and consisting of a set of circular cones fitting one into another in inverted positions. Usually consists of fibrous *calcite* and rarely of *siderite* and *gypsum*. The sides are often fluted, ridged and grooved.
- Crystal lattice** Three-dimensional atomic arrangement of a crystal, each point of which has identical surroundings.
- Crystalline** Pertaining to or having the nature of a crystal, or formed by crystallization. Having a crystal structure or a regular arrangement of atoms in a space lattice. Said of rocks consisting wholly of crystals or crystal fragments, especially igneous or metamorphic rocks that do not contain glass.
- Crystallographic axes** One of three (four in a hexagonal crystal) imaginary lines in a crystal that pass through its center; used in describing crystal structure and symmetry.
- Crystal symmetry** The repeat pattern of similar crystal faces that indicates the ordered internal arrangement of a mineral.
- Cube** An isometric crystal form of six equivalent and perpendicular faces.
- Diabase** A dark-colored, fine-grained, intrusive igneous rock composed mainly of *plagioclase (labradorite)* and *pyroxene*. The *plagioclase* crystals are larger and embedded in a groundmass of *pyroxene* crystals.
- Diorite** A generally one-half dark and one-half light-colored igneous rock with a granite texture, consisting mostly of sodium *plagioclase (andesine)* and *hornblende, biotite* or *pyroxene*.
- Dodecahedron** An isometric crystal form composed of 12 faces, rhombic or pentagonal. Each face is parallel to one crystallographic axis and intersects the other two.
- Dome** An open crystal form composed of two nonparallel faces that intersect along and astride a symmetry plane.

- Druse** A mineral surface covered with many small projecting crystals; an opening or cavity in rock whose interior surface is lined with small crystals.
- Drybone ore** An earthy, friable honeycombed variety of *smithsonite*, found in veins or beds in limestone or dolomite and accompanying sulfides of zinc, lead and iron.
- Feldspathoids** A group of comparatively rare minerals chemically related to the *feldspars*, but differing in crystal form and physical properties. They consist of aluminosilicates of sodium, potassium or calcium that contain insufficient silica to form *feldspar*. They take the place of *feldspar* in igneous rocks that are too low in silica or contain excess alkalis and aluminum for the *feldspars* to form.
- Fissile** Capable of being split easily along closely spaced parallel planes.
- Flowstones** A term for any cave formation of calcium carbonate or other mineral formed by flowing water on the walls or floor of a cave.
- Gabbro** A dark-colored, coarse-grained, intrusive igneous rock composed principally of calcium *plagioclase* (*labradorite*), *clinopyroxene* and with or without *olivine* and *orthopyroxene*. *Apatite* and *magnetite* are common accessory minerals. It is the approximate intrusive equivalent of basalt.
- Gangue** The valueless rock or mineral aggregates in an ore; that part of the ore that is not economically desirable.
- Gneiss** A banded rock formed by metamorphism in which bands of granular minerals alternate with bands of flaky or elongate prismatic minerals. Varieties are determined by texture, dominant mineral or general composition, e.g., augengneiss, *hornblende*-gneiss, granite-gneiss.
- Granite** A light-colored coarse-grained, igneous rock composed dominantly of alkali *feldspar* and *quartz*. Sodium *plagioclase* (usually *oligoclase*) commonly is present in small amounts and *muscovite*, *biotite*, *hornblende* or rarely *pyroxene* may be constituents.
- Hydrated** Said of a mineral in which water is chemically combined with another substance.
- Interfacial angle** The angle between two faces of a crystal.
- Ion** An atom or group of atoms with an electric charge (cation-positive ion, anion-negative ion).
- Jack** Miner's term for *sphalerite*; also called *blackjack* and *blende*.
- Lapidarist** One who is a cutter, grinder and polisher of colored stones or of precious stones other than diamonds.
- Marble** A metamorphosed limestone or dolomite that is recrystallized and usually has a saccharoidal texture (like wet sugar) and is capable of taking a polish.

- Massive** A mineral without definite internal structure, e.g., one lacking a platy or fibrous structure. (Note: mineralogists do not recommend this usage.)
- Microperthite** A variety of alkali *feldspar* and intergrown *albite* veins in which the intergrowths can be seen only with a microscope.
- Mineraloids** A naturally occurring, usually inorganic substance that is not considered to be a mineral because it is amorphous and thus lacks characteristic physical and chemical properties, e.g., opal.
- Molecule** The smallest combination of atoms that will form a given chemical compound.
- Nodular** Composed of nodules or occurring in the form of nodules.
- Nodule** A small, hard, and irregular or rounded body (knot, mass, lump) of a mineral or mineral aggregate, normally having a warty or knobby surface and no internal structure, and usually exhibiting a different composition from and a greater hardness than the enclosing sediment. Examples: *chert* nodules in limestone and *pyrite* nodules in coal beds. Most nodules appear to be secondary structures. They can be separated as discrete masses from the host material.
- Octahedron** An isometric crystal form of eight faces which are equilateral triangles.
- Opalescent** A milky or somewhat pearly appearance or luster of a mineral, such as that shown by *opal*, *labradorite* and *moonstone*.
- Opaque** Said of a mineral that will not transmit light; impervious to the rays of light.
- Orthodome** The four faces parallel to the orthoaxis, *b*, of monoclinic crystals and meeting the other two axes.
- Oxidation** Process of combining with oxygen, e.g., oxidation of Fe gives FeO, of Zn, ZnO. It results in an increase in positive valence and a decrease in negative valence, e.g., Cu^+ is oxidized to Cu^{++} and S^{--} is oxidized to S.
- Pegmatite** Coarse-grained igneous rocks usually occurring as dikes associated with a large mass of plutonic igneous rock of finer grain size. The relative grain size has more bearing than the absolute size. Usually means granite pegmatite. May contain rare minerals and large crystals.
- Penetration twin** A twinned crystal, an intergrowth of two crystals of the same species, the individuals of which appear to have grown through one another.
- Perthitic** A texture occurring in alkali *feldspar* (usually *microcline*) with parallel or subparallel intergrowths of *albite*. The intergrowths typically form small strings or irregular veinlets.
- Petrification** A type of fossilization in which organic matter is converted into stone by infiltration of water that has calcium carbonate or silica in solution which replaces the original organic materials, sometimes retaining the original structure.

- Phenocryst** A large and easily seen mineral crystal in an igneous rock with a porphyritic texture.
- Pinacoid** A crystal form consisting of two parallel faces. Variations are basal pinacoid, side pinacoid and front pinacoid.
- Porphyry** An igneous rock of any composition that has large crystals (phenocrysts) set in a fine-grained groundmass, e.g., diorite porphyry.
- Prism** A crystal form of three or more similar faces parallel to a single axis, and which is open only at the ends of the axis parallel to the faces.
- Prismatic** Referring to a crystal prism.
- Puddingstone** A popular name for a conglomerate in which the rounded pebbles or cobbles have a markedly different color than the fine-grained matrix or cement.
- Pyritohedron** A crystal form of the isometric system with 12 pentagonal faces that are not regular. A pentagonal dodecahedron. Named after pyrite which commonly occurs in this form.
- Quartzite** A metamorphosed sandstone consisting dominantly of *quartz* and formed by recrystallization of sandstone or *chert*. Unmetamorphosed sandstones solidly cemented by secondary silica are called orthoquartzites or quartzitic sandstones.
- Refractive index** When a ray of light passes through air or a vacuum into a mineral its velocity is changed and it is deflected from a straight path. The index of refraction is given as a number which expresses the ratio of the velocity of light in a vacuum to the velocity of light in a mineral.
- Replacement** A process in which a new mineral of different chemical composition may grow in the body of an old mineral or mineral aggregate by simultaneous capillary solution and deposition.
- Rhyolite** An extrusive igneous rock with a composition equivalent to granite. It is generally porphyritic, with phenocrysts of *quartz* and alkali *feldspar* in a fine to glassy groundmass.
- Rosette** A flower-like crystal growth resembling a rose, seen in *gypsum*, *barite*, *pyrite* and *hematite*.
- Scalenoedron** A crystal form of the tetragonal and hexagonal systems consisting of faces that are scalene triangles, i.e., that have unequal sides and angles.
- Schist** Any metamorphic crystalline rock with a strongly foliated structure that is easily split into irregular plates because of the subparallel arrangement of micaceous minerals which are the dominant constituent.
- Secondary mineral** A mineral that formed from alteration of primary minerals as a result of weathering, metamorphic or solution activity.

Sectile Said of a mineral that is tough enough to be cut with a knife without breaking into pieces.

Silicified Replaced by silica.

Slate A compact, fine-grained, metamorphic rock formed from shale or clay and possessing fissility (slaty cleavage).

Sphenoid An open crystal form having two nonparallel faces that are symmetrical to an axis of twofold symmetry. Found in the monoclinic, orthorhombic and tetragonal systems.

Striated A condition of having shallow, parallel depressions or bands on the cleavage face of a mineral as in *pyrite*, *plagioclase feldspar* and *quartz*.

Substitution The partial or complete replacement of one or more ions in a crystal by other types of ions of generally similar size and charge.

Syenite A coarse-grained plutonic igneous rock consisting of alkali *feldspar*, one or more dark minerals, especially *hornblende*, and a small amount of *plagioclase* and *quartz*.

Tetrahedron An isometric crystal form with four faces each with equal intercepts on all three axes, e.g., *sphalerite* crystals. Resembles sphenoidal forms like *chalcopyrite* crystals which are tetragonal.

Trachyte A fine-grained, generally porphyritic igneous rock composed essentially of alkali *feldspar* and minor *biotite*, *hornblende* or *pyroxene*. The extrusive and mineralogical equivalent of syenite.

Translucent Capable of transmitting light, but not transparent.

Transparent Capable of transmitting light and through which an object can be seen.

Trapezohedron Crystal forms of the isometric, tetragonal and hexagonal systems. In the isometric form there are 24 faces each of which is a 4-sided figure, no two sides of which are parallel (a trapezium). In the tetragonal and hexagonal forms there are 6, 8, or 12 faces that are trapeziums, half of which are above and offset from the other half below.

Traprock Dark-colored fine-grained igneous rocks that originated in dikes or flows e.g., diabase or basalt.

Twinning plane The plane across which the individual parts of a twin crystal are symmetrically arranged or reflected.

Vesicle A small cavity or space in a fine-grained igneous rock formed by expansion of a bubble of gas or steam.

Vug A small cavity in a rock usually lined with crystals that may have a different mineral composition than the enclosing rock.

Appendix I

SUMMARY OF MINERALS, GEMSTONES AND CUTTING MATERIALS AVAILABLE IN IOWA

Limestone and dolomite exposures
and quarries

Aragonite
Barite
Calcite
Celestite
Chalcedony
Chalcopyrite
Chert, banded
Dolomite
Fluorite
Galena
Glaucinite
Goethite
Hexagonaria
Limonite
Lithostrotion
Marcasite
Mexican onyx
Millerite
Pyrite
Pyrolusite dendrites
Quartz
Sphalerite
Smithsonite
Wurtzite

Shale exposures and pits

Clay ironstone (siderite concretions)

Clay minerals
Gypsum (selenite)
Hematite concretions
Marcasite
Pyrite
Radioactive minerals

Sandstone exposures

Glaucinite
Hematite
Limonite
Marcasite
Pyrite
Quartz
Siderite (clay ironstone)

Geodes

Ankerite
Aragonite
Barite
Calcite
Chalcedony
Clay minerals
Dolomite
Goethite
Malachite (?)
Marcasite
Millerite
Pyrite

Quartz
Selenite
Sphalerite

Gravel pits and glacial
boulders

Agate (Lake Superior,
carnelian, eye, Montana
type)
Amphibole (hornblende)
Chert
Chalcedony
Copper, native
Diamond
Epidote
Feldspar (microcline,
orthoclase, plagioclase)
Garnet (almandine)
Gold
Hexagonaria fragments
Jasper
Magnetite (crystalline
and black sands)
Mica (biotite, muscovite)
Petritified wood (chertified;
also casts of fine sandstone
of the bark)
Pyroxene
Quartz, crystalline
Zeolites

Coal strip mines

Ankerite
Apatite
Barite
Calcite
Chalcopyrite
Dolomite
Goethite
Gypsum (selenite)
Halotrichite
Hematite and hematite
concretions
Limonite
Marcasite
Malachite
Melanterite
Petrified wood (calcified, and
silicified (minor), and
as sandstone casts)
Pyrite
Quartz
Septarian concretions and
veins in limestone
Siderite, clay ironstone
concretions
Sphalerite
Sulphur

Dubuque and northeastern Iowa
zinc-lead area

Anglesite
Aragonite
Azurite (?)
Barite
Calcite
Cerussite
Chalcocite (?)
Dolomite
Galena
Limonite
Malachite
Marcasite
Millerite (?)
Pyrite
Silver (?)
Smithsonite
Sphalerite
Wurtzite

Fort Dodge and Sperry mines

Anhydrite
Celestite
Gypsum

Keswick-Ollie area

Barite
Calcite

Chalcedony (banded)
Dolomite
Glaucosite
Goethite
Millerite
Pyrite
Pyrolusite dendrites
Quartz (crystalline and
druzy)

Pint's quarry, Raymond

Barite
Calcite
Chalcopyrite
Fluorite
Goethite
Limonite
Marcasite
Pyrite
Quartz
Sphalerite
Wurtzite (?)

Waukon area

Goethite
Hematite
Limonite

Appendix II

LOCATION OF RESOURCE MINERAL COLLECTIONS FOR
EXAMINATION OF MINERALS OF IOWA AND OTHER STATES

1. Cornell College, Department of Geology, Mt. Vernon (appointment recommended).
2. Davenport Public Museum, 1717 West 12th Street, Davenport.
3. Drake University, West 28th Street and University Avenue, Des Moines.
4. Iowa Geological Survey, Trowbridge Hall, University of Iowa, Iowa City.
5. Iowa State Historical Museum, East 12th and Grand, Des Moines.
6. University of Northern Iowa, Department of Earth Science, Cedar Falls. (See also the University Museum in the Physical Plant Building on Highway 57.)
7. Waterloo Museum (Grout Museum), Park Avenue at South Street, Waterloo.
8. Porter House Museum, 410 West Broadway, Decorah.

Private collections seen by appointment only:

9. Mr. and Mrs. Dean Anderson, 2910 Cornell, Iowa City.
10. Mr. and Mrs. Joe Groves, rural South English.
11. Mr. and Mrs. Ed Hix, 1304 Clark Street, Dysart.
12. Mr. and Mrs. Roland Kinzie, 1727 Plymouth Street, Waterloo.
13. Mr. Frank A. Masick and Mr. Frank A. Masick, Jr., Lovilia.
14. Mr. and Mrs. Ed Mc Namar, 3513 57th Street, Des Moines.
15. Dr. and Mrs. Howard R. Shanks, 1429 Clark Avenue, Ames.

Many of the Rock and Mineral Clubs in Iowa periodically have shows or swaps which usually are announced in club bulletins, local papers, or on the radio. Much practical information on minerals and gemstones can be picked up at these meetings.

Appendix III

TABLE FOR IDENTIFYING SOME IOWA MINERALS

I. Luster metallic or submetallic

A. Hardness 2.5 or less (soft enough to mark paper)

COLOR	STREAK	HARDNESS	SPECIFIC GRAVITY	CLEAVAGE	FRACTURE	REMARKS	NAME AND COMPOSITION
Black to bluish-black	Black to bluish-black	2.0-2.5 (up to 6.5 for crystals)	4.4-5.0	Prismatic	Uneven, brittle	Commonly as dendritic coatings on bedding planes of sedimentary rocks and as dendrites in chalcedony (moss agate) . Massive and fibrous varieties may be soft and sooty.	PYROLUSITE MnO ₂
Dark lead gray	Dark lead gray	2.5	7.58	Cubic, highly perfect in 3 directions	Flat sub-conchoidal	Isometric. Typically heavy with cubic cleavage and brilliant metallic luster on fresh surfaces. Associated with sphalerite, pyrite, marcasite, chalcopyrite, calcite and barite .	GALENA PbS

B. Hardness 2.5 to 5.5 (will not readily mark paper; can be scratched by a knife)

Copper-red, tarnishes brown to black	Copper-red, shiny, metallic	2.5-3.0	8.8-8.9	None	Hackly	Highly malleable; very heavy; usually found in massive or wire-like groups in gravel pits or glacial drift. Oxidizes greenish (malachite).	NATIVE COPPER Cu
Deep gold or brass yellow	Greenish-black	3.5-4.0	4.1-4.3	Indistinct	Uneven, brittle	Tetragonal. Softer than pyrite and marcasite . Often tarnishes bluish. Usually massive. Crystals commonly in sphenoids.	CHALCOPYRITE CuFeS ₂
Dark brown to black on fresh surface; yellow to light brown on weathered surface	Yellow-brown	5.0-5.5	3.6-4.0	None	Uneven, splintery, earthy, brittle	Amorphous, compact, botryoidal, cellular, stalactitic, fibrous. The earthy variety may be soft and ochreous (yellow ochre).	LIMONITE FeO (OH) . nH ₂ O

C. Hardness 5.5 or greater (cannot be scratched by a knife)

COLOR	STREAK	HARDNESS	SPECIFIC GRAVITY	CLEAVAGE	FRACTURE	REMARKS	NAME AND COMPOSITION
Steel gray to iron black; earthy varieties dull red	Dark red	5.5-6.5 (may be soft in earthy varieties)	4.9-5.3	None; parting rhombohedral, nearly cubic	Uneven to Subconchoidal	Hexagonal scalenohedral. Commonly with triangular, striated crystal faces or in oolitic aggregates. Brownish-red streak characteristic. The soft earthy variety is called red ochre .	HEMATITE Fe ₂ O ₃
Black	Black	5.5-6.5	5.2	None; parting octahedral	Subconchoidal to uneven	Isometric. Strongly magnetic. Crystals octahedral or dodecahedral. Found in igneous and metamorphic rocks and in black sands. Infusible. Dissolves slowly in concentrated HCl.	MAGNETITE Fe ₃ O ₄
Pale brass yellow; tarnishes brown and may be iridescent	Greenish-black to brownish-black	6.0-6.5	4.9-5.0	Indistinct	Uneven, brittle	Isometric crystals forming cubes, octahedrons and pyritohedrons. Faces often striated. Commonly as compact, granular, botryoidal masses and disseminated. Insoluble in HCl. Fine powder soluble in HNO ₃ .	PYRITE FeS ₂
Pale brass yellow to almost white	Greenish-black to brownish-black	6.0-6.5	4.88	Prismatic in 2 directions at about 75°, poor to indistinct	Uneven, brittle	Orthorhombic. Twins common as cockscomb forms. Compact, rounded concretions with radiating fibrous structure. Lighter colored than pyrite . More easily decomposed than pyrite .	MARCASITE FeS ₂

II. Luster nonmetallic

A. Hardness 2.0 or less (can be scratched by fingernail)

Dull green to yellowish-green and darker	Light green to greenish-white	1.0-2.0	2.2-2.4	None	Uneven, earthy	Greensand. Glassy to dull luster. Granular, earthy to amorphous. Disseminated in limestone, dolomite, sandstone and clay.	GLAUCONITE approx. KFe(SiO ₃) ₂ · H ₂ O
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COLOR	STREAK	HARDNESS	SPECIFIC GRAVITY	CLEAVAGE	FRACTURE	REMARKS	NAME AND COMPOSITION
White to yellowish or greenish	Uncolored	1.5	1.8-1.9	Poor	Conchoidal, brittle	Usually as matted or acicular hair-like crystal aggregates on marcasite and pyrite or as an incrustation. Astringent taste.	HALOTRICHITE $\text{FeSO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 22\text{H}_2\text{O}$
White to gray, may be yellow or red	White	1.5-2.0	2.3-2.4	3 directions; perfect side pinacoid and 2 others less conspicuous	Conchoidal, splintery, brittle	Monoclinic. Luster glassy, pearly, shining. In flat lengthened crystals (selenite), transparent to translucent, often twinned; fibrous (satin spar); massive (alabaster).	GYPSUM $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$

B. Hardness 2.0 to 3.5 (cannot be scratched by a fingernail; can be scratched by a coin)

Colorless, White, gray, brown, amber green, rose	Uncolored to white	2.5-3.0	2.77-3.0	Perfect basal	Flexible, elastic, tough	Monoclinic. Six-sided crystals (hexagonal outline). In granites and gneisses. Flaky and scaly. Transparent to translucent.	MUSCOVITE $\text{KAl}(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$
Black, brownish-black, greenish-black, tinged yellowish	White	2.5-3.0	2.8-3.3	Perfect basal	Flexible, elastic, tough	Monoclinic. Six-sided crystals (hexagonal outline). In igneous and metamorphic rocks and pegmatites. Usually translucent to opaque.	BIOTITE $\text{K}(\text{Mg,Fe})_3(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$
White to light gray	Uncolored to white	2.5-3.0	6.38	3 directions; basal and prismatic, good and distinct; trace of side pinacoid	Conchoidal, brittle	Orthorhombic. Usually associated with galena after which it forms pseudomorphs. Commonly massive and earthy around cores of galena .	ANGLESITE PbSO_4
Colorless, white and variously tinted	White or grayish	3.0 (on cleavage face)	2.7	Perfect rhombohedral in 3 directions	Conchoidal, but seldom seen	Hexagonal rhombohedral. Very abundant in limestones. Numerous forms. Dissolves in HCl. Transparent. May luminesce under ultraviolet light.	CALCITE CaCO_3

COLOR	STREAK	HARDNESS	SPECIFIC GRAVITY	CLEAVAGE	FRACTURE	REMARKS	NAME AND COMPOSITION
Colorless, white, yellow, brown, pink, blue	White	3.0-3.5	4.3-4.6	3 directions; basal and prismatic, distinct; side pinacoid indistinct	Uneven, brittle	Orthorhombic. Resembles calcite and selenite , but is noticeably heavier. Tabular crystals. Compact, radial masses of divergent plates forming "crested" barite .	BARITE BaSO ₄
White, gray, bluish and reddish	White	3.0-3.5	2.9-3.0	3 directions; pinacoids, forming rectangular crystals or cleavable masses	Uneven, splintery, brittle	Orthorhombic. Usually massive. Crystals rare. Not found at surface exposures in Iowa. Does not contain water. Soluble in HCl.	ANHYDRITE CaSO ₄
Colorless, white, gray, bluish, and reddish	White	3.0-3.5	3.96-3.98	3 directions; perfect basal, good prismatic, poor side pinacoid	Uneven, brittle	Orthorhombic. Associated with gypsum . Tabular crystals. Heavy. Transparent to translucent. Crimson flame in blowpipe test. Does not bubble in acid like calcite .	CELESTITE SrSO ₄
Colorless, white, and gray	White	3.0-3.5	6.4-6.6	Prismatic	Conchoidal, brittle	Orthorhombic. Associated with galena . Intergrown crystal lattices, granular compact masses, crust-like coatings. Adamantine to glassy luster. Bubbles in HNO ₃ . Extremely heavy.	CERUSSITE PbCO ₃

C. Hardness 3.5 to 5.5 (cannot be scratched by a coin; can be scratched by a knife)

Yellowish-brown, brown to dark brown and reddish-brown on weathering	White	3.5	3.02 increasing with increase in Fe and Mn	Perfect rhombohedral in 3 directions	Subconchoidal, brittle	Hexagonal rhombohedral. In septarian concretion vugs and in geodes. Brown curved crystal aggregates. Darkens and becomes magnetic when heated. Associated with calcite and quartz . Transparent to translucent.	ANKERITE CaFe (CO ₃) ₂
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COLOR	STREAK	HARDNESS	SPECIFIC GRAVITY	CLEAVAGE	FRACTURE	REMARKS	NAME AND COMPOSITION
Colorless, white and variously tinted	White	3.5-4.0	2.8-2.9	Perfect rhombohedral in 3 directions	Subconchoidal, brittle	Hexagonal rhombohedral. Crystal aggregates in small, curved forms. Bubbles slowly in cold HCl. Not as abundant as calcite which it resembles.	DOLOMITE CaMg(CO ₃) ₂
Colorless, white and variously tinted	White	3.5-4.0	2.94	3 directions, only one, the side pinacoid being distinct	Subconchoidal, brittle	Orthorhombic. Twin crystals common.	ARAGONITE CaCO ₃
Brown, black and yellow are common, may be white, red or green	Brownish to light yellow and white	3.5-4.0	3.9-4.1	Perfect dodecahedral in 6 directions	Conchoidal, uneven, brittle	Isometric. As crystals and cleavable masses forming tetrahedrons and dodecahedrons. Dissolves in HCl with odor of rotten eggs.	SPHALERITE ZnS
Brown and gray of various shades, often yellowish, tarnishes darker, sometimes iridescent	White to pale yellow	3.7-4.2	3.96 (pure); lower when Mn, Mg, and Ca substitute for Fe	Perfect rhombohedral in 3 directions	Uneven, conchoidal, brittle	Hexagonal rhombohedral. Usually found as clay ironstone concretions in shales and coal beds of Pennsylvanian and Cretaceous age. Heavy. Blackens and becomes magnetic on heating.	SIDERITE FeCO ₃
Colorless, violet, blue, green, yellow, white, brown and pink	White	4.0	3.18	Perfect octahedral in 4 directions	Uneven, brittle	Isometric. Glassy crystals in cubes and octahedrons, penetration twins common, cleavable masses, granular. Transparent to translucent. May be luminescent in ultraviolet light.	FLUORITE CaF ₂
Gray and white to tan, may be green, blue or brown	White	4.0-4.5	4.0-4.45	Imperfect rhombohedral, but difficult to see	Uneven, subconchoidal, brittle	Hexagonal rhombohedral. Rarely well crystallized; commonly porous masses called drybone , may occur in botryoidal and stalactitic forms, crystalline incrustations, compact massive, coarse granular and earthy. Soluble in HCl. Heavy.	SMITHSONITE ZnCO ₃

COLOR	STREAK	HARDNESS	SPECIFIC GRAVITY	CLEAVAGE	FRACTURE	REMARKS	NAME AND COMPOSITION
Black, blackish-brown, brownish-yellow, reddish-brown	Yellowish-brown	5.0-5.5	3.3-4.3	Perfect side pinacoid	Uneven, brittle	Orthorhombic. Crystals tiny, slender, prismatic, striated. In geodes and vugs. Usually massive, may be botryoidal, stalactitic. Soluble in HCl. Fuses with difficulty and becomes magnetic.	GOETHITE HFeO_2

D. Hardness 5.5 to 7.5 (cannot be scratched by a knife)

Dark green, dark brown to black	Uncolored or paler than the color	5.0-6.0	2.9-3.4	Perfect prismatic at 56° and 124° ; front and side pinacoids sometimes distinct; terminated by a low dome	Uneven, splintery, brittle	Monoclinic. Crystals short to long prismatic six-sided, wedge-shaped on ends; columnar, fibrous and granular massive. In igneous and metamorphic rocks. Associated with feldspar, quartz, pyroxenes, chlorite.	HORNBLende $\text{CaNa}(\text{Mg,Fe})_4(\text{Al,Fe,Ti})_3\text{Si}_6\text{O}_{22}(\text{O,OH})_2$
black, greenish-black to dark green	White to gray and grayish-green	5.0-6.0	3.2-3.4	Imperfect prismatic at 87° and 93° ; basal parting may be distinct	Uneven, conchoidal	Monoclinic. Crystals short, prismatic, 4- to 8-sided, square in cross section, lamellar, granular, fibrous. In darker igneous rocks. Common as twins. Insoluble in HCl.	AUGITE $\text{Ca}(\text{Mg,Fe,Al})(\text{Si,Al})_2\text{O}_6$
Commonly flesh-red, may be colorless, white, cream and gray	White	6.0	2.56-2.59	Perfect basal, and side pinacoid less perfect at 90° ; imperfect prismatic	Uneven, conchoidal, brittle	Monoclinic. Crystals usually prismatic. Twins common. In granites and porphyritic rocks. Blocky cleavage fragments. Insoluble in acids. Fuses with difficulty.	ORTHOCLASE $\text{K}(\text{AlSi}_3\text{O}_8)$
White, cream, flesh-pink, reddish-brown and green	White	6.0-6.5	2.54-2.57	Perfect basal, and side pinacoid less perfect at $89\frac{1}{2}^\circ$; imperfect prismatic	Uneven, brittle	Triclinic. Crystals large resembling orthoclase , but have coarse perthite structure. Green varieties are called amazonite . In pegmatites.	MICROCLINE $\text{K}(\text{AlSi}_3\text{O}_8)$

COLOR	STREAK	HARDNESS	SPECIFIC GRAVITY	CLEAVAGE	FRACTURE	REMARKS	NAME AND COMPOSITION
Colorless, white or gray, and various colors from inclusions; may show blue-green play of colors in albite and labradorite	Uncolored to white	6.0-6.5	2.62 in albite increasing to 2.76 in anorthite	Perfect basal, and good side pinacoid at 93-94°; imperfect prismatic	Uneven, conchoidal	Triclinic. Crystals not common. Usually in cleavable masses or granular. Parallel twinning striations on cleavage faces. In volcanic and igneous rocks.	PLAGIOCLASE FELDSPARS Na (AlSi ₃ O ₈) Ca (Al ₂ Si ₂ O ₈)
Yellow-green of various shades, light brown and black	Uncolored to grayish	6.0-7.0	3.25-3.5	Perfect basal, imperfect front pinacoid	Uneven, brittle	Monoclinic. Crystals usually prismatic and elongated. Acicular, striated vertically, granular crystalline, massive. Pistachio green color is unique. Glassy luster. Magnetic after heating on charcoal.	EPIDOTE Ca ₂ (Al, Fe) ₃ (SiO ₄) ₃ (OH)
Typically deep red to purplish-red, also brownish-red and black	White	6.5-7.5	4.25-4.31	None, but may show distinct parting on dodecahedron faces	Subconchoidal, uneven, brittle	Isometric. Crystals commonly as dodecahedrons or trapezohedrons. Seed-like grains in metamorphic rocks such as schist and gneiss; also in pegmatites.	GARNET (Almandine) Fe ₃ Al ₂ (SiO ₄) ₃
Colorless, various shades of yellow, red, brown, green, blue and black	White or paler than the color when impure	7.0	2.65	Indistinct and rarely seen	Conchoidal to subconchoidal, brittle, tough	Hexagonal rhombohedral. Crystals six-sided prisms with rhombohedrons on one or both ends and resembling pyramids if equally developed. Faces horizontally striated. Twins common. Massive granular and crystalline to compact cryptocrystalline (chert and chalcedony). In sands and gravels, sandstones, quartzites and geodes. Glassy to waxy luster. Transparent to opaque.	QUARTZ SiO ₂

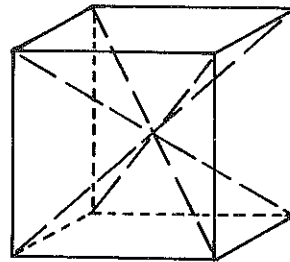
Appendix IV

ILLUSTRATIONS OF MINERAL CRYSTALS WITH DISCUSSIONS ON TWINS, PSEUDOMORPHS AND PHANTOMS

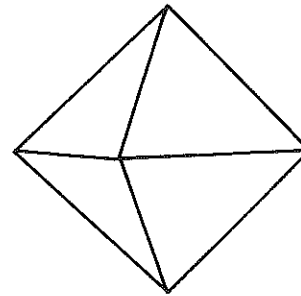
Isometric or cubic system

Minerals in this system have four diagonal, three-fold axes of symmetry or six diagonal, two-fold axes of symmetry. *Galena*, *pyrite*, *fluorite*, *garnet* and *sphalerite* are examples. They tend to form cubes or balls and have a similar appearance from many viewpoints.

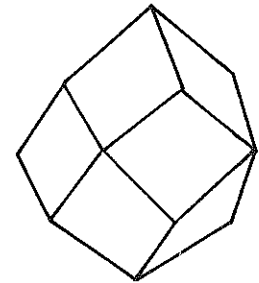
Cube



Octahedron

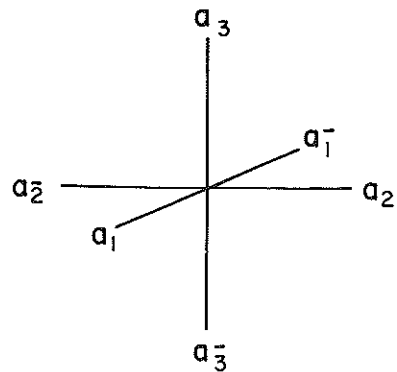


Dodecahedron

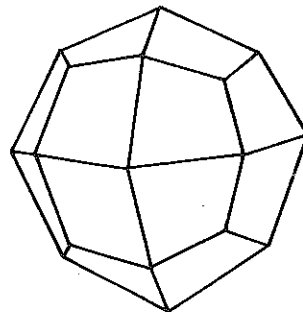


Galena, Fluorite, and Pyrite

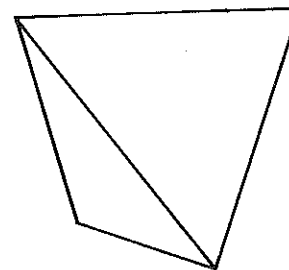
Garnet



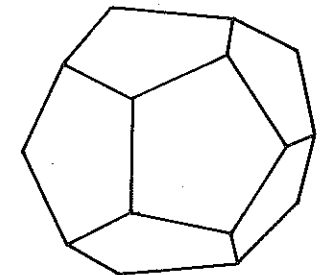
Trapezohedron



Tetrahedron



Pyritohedron



Garnet

Sphalerite

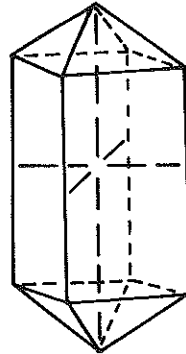
Pyrite

Figure 2. Mineral Crystals, Isometric

Tetragonal system

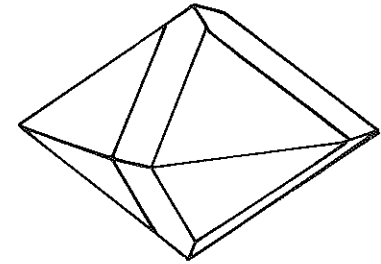
Minerals in this system have one vertical, four-fold axis of symmetry or four horizontal two-fold axes of symmetry. *Zircon*, *rutile*, *cassiterite* and *chalcopyrite* are examples. They exhibit squarish cross sections, usually forming long and sometimes slender crystals.

Prism and
Bipyramid

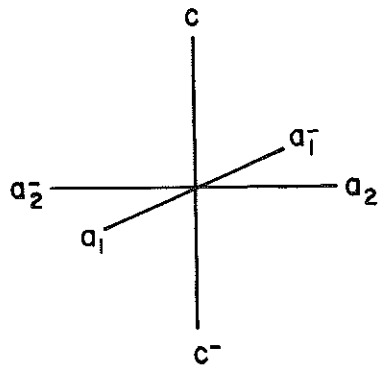


Zircon

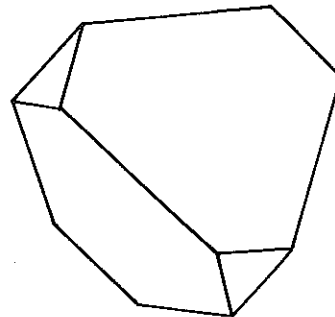
Double
Bipyramid



Cassiterite

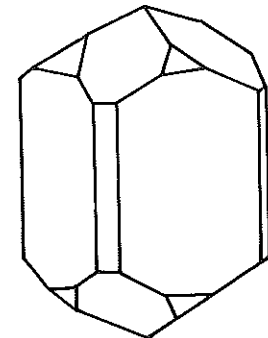


Sphenoids



Chalcopyrite

1st and 2nd Prisms
and Pyramids

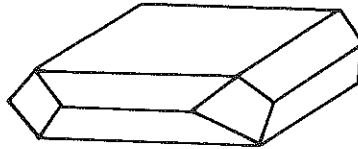


Rutile

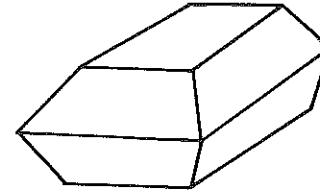
Orthorhombic system

These minerals have three two-fold axes of symmetry or one vertical, two-fold axis and two horizontal two-fold axes of symmetry. Examples are *barite*, *marcasite*, *goethite* and *aragonite*. They usually are rectangular or diamond-shaped in cross section and stubby to short prismatic.

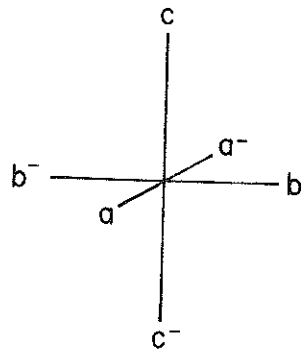
Prism, Basal Pinacoid, Domes



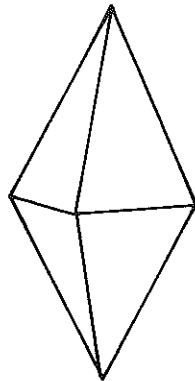
Barite



Barite

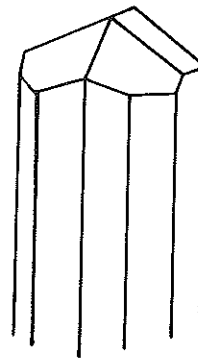


Pyramids



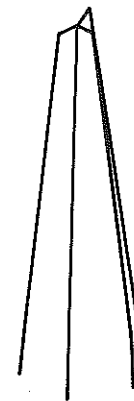
Sulfur

Prism, Basal Pinacoid
Domes and Pyramid



Goethite

Prism, Side Pinacoid
and Acute Domes



Aragonite

Figure 4. Mineral Crystals, Orthorhombic

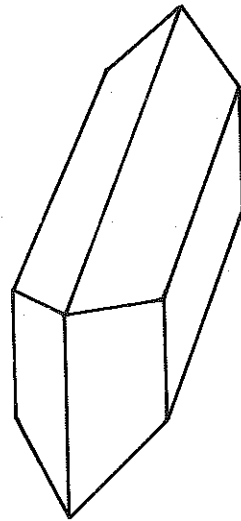
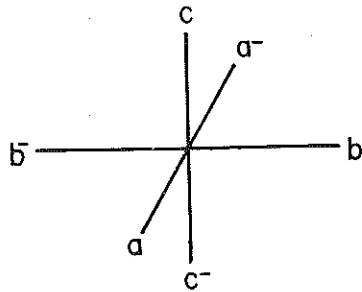
Monoclinic system

Monoclinic minerals have one two-fold axis of symmetry or one plane of symmetry. *Selenite*, *orthoclase* feldspar, *hornblende* and *muscovite* mica are examples. They usually are blocky or stubby crystals with unbalanced faces matching only on opposite ends.

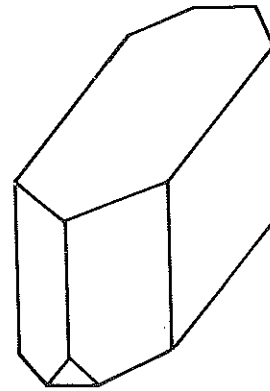
Side Pinacoid,
Pyramid and Prism

Side and Basal Pinacoid
Prism and Orthodome

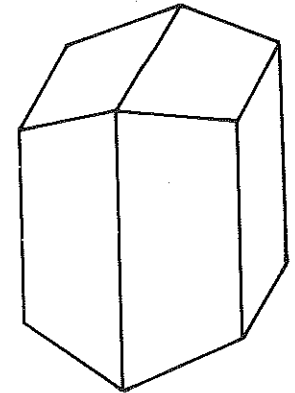
Side Pinacoid, Prism
and Clinodome



Selenite



Orthoclase



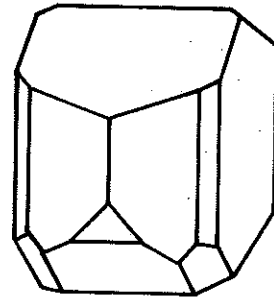
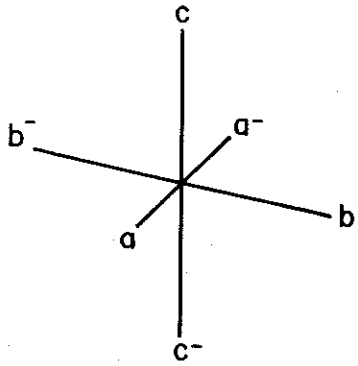
Hornblende

Figure 5. Mineral Crystals, Monoclinic

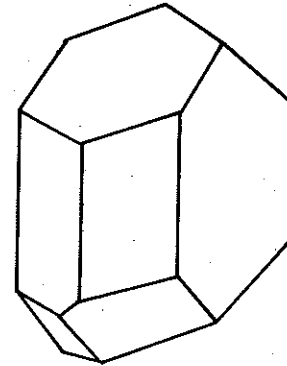
Triclinic system

The minerals in this system have only a center of symmetry or a one-fold axis of symmetry. Only pairs of faces may be symmetrical. The center of symmetry is the only element of symmetry left. *Microcline* and the *plagioclase* feldspars are examples.

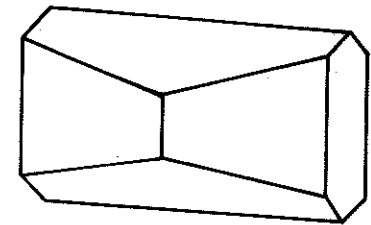
Pinacoids, Prisms, Domes



Microcline



Oligoclase



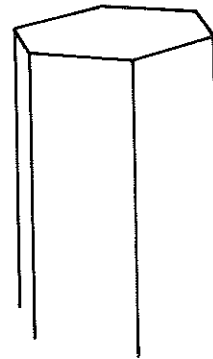
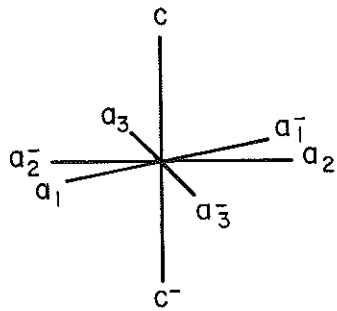
Albite

Figure 6. Mineral Crystals, Triclinic

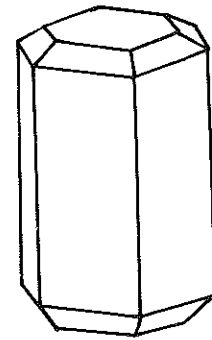
Hexagonal system

Hexagonal minerals have one vertical, six-fold axis of symmetry (Hexagonal Division) or one vertical, three-fold axis of symmetry (Trigonal or Rhombohedral Division). Examples are *beryl*, *apatite*, *quartz*, *calcite* and *smithsonite*. They usually have hexagonal or triangular cross sections and are columnar or have short to long prisms with cone-like or rhombic ends.

Hexagonal Division



Beryl

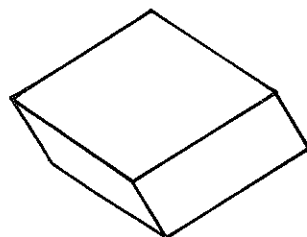


Apatite

Figure 7. Mineral Crystals, Hexagonal

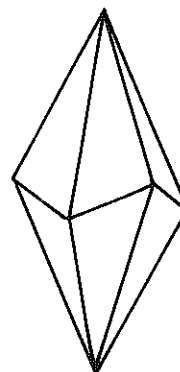
Trigonal or Rhombohedral Division

Rhombohedron



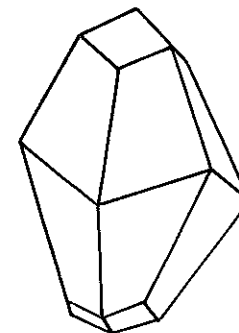
Calcite

Scalenoehedron

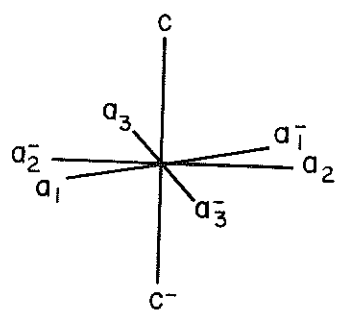


Calcite

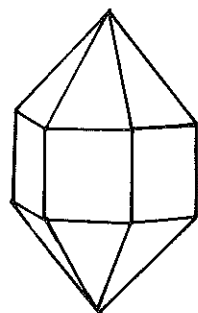
Rhombohedron and
Scalenoehedron



Calcite

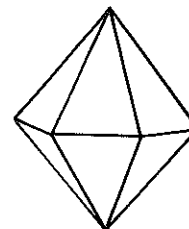


Prismatic



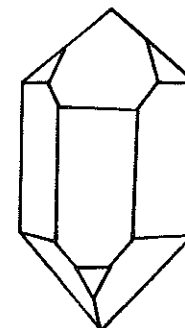
Quartz

Hexagonal
Rhombohedral



Quartz

Prisms and
Pyramids



Quartz

Figure 8. Mineral Crystals, Hexagonal

Twin Crystals

Eventually, every mineral collector will run across twin crystals. Because crystals commonly grow in groupings, in certain types of minerals it is not uncommon to find twins, which are two crystals in contact along a plane or completely intergrown. Contact twins are united along a prominent twinning plane. As shown in most textbooks, the two individuals are symmetrically arranged on either side of this plane as mirror images. In the field, however, you usually find one of the crystals predominating. Good examples are found in *selenite* fish-tail twins and in *calcite* (plates 2 and 8). Penetration twins are two or more whole crystals completely piercing each other. You can see this well in *selenite*, *fluorite*, *galena*, and *pyrite* (plates 7 and 8). The striations of the plagioclase feldspars *albite* and *oligoclase* are due to repeated twinning, or parallel repetition in reversed position of crystalline layers. Some Iowa minerals that you might commonly find as twins are *calcite*, *quartz*, *galena*, *sphalerite*, *pyrite*, *marcasite*, *selenite*, *fluorite*, and the *plagioclase feldspars*. Additional twin crystals are shown in Figure 9.

Pseudomorphs

As you broaden your reading from the elementary rock and mineral books to those with a fuller and more serious treatment of minerals, you will occasionally run across the word pseudomorph. A pseudomorph is a mineral having the outward crystal form common to another mineral. The original mineral was changed to another mineral by substitution or alteration, while retaining the original form. Literally, the word pseudomorph means "false-form". It is described as being "after" the mineral whose form it has. Typical pseudomorph minerals found in Iowa are *limonite* ($\text{FeO}(\text{OH})\cdot n\text{H}_2\text{O}$) or *goethite* (HFeO_2) after *pyrite* (FeS_2), and petrified wood (silicified or calcified) after organic wood.

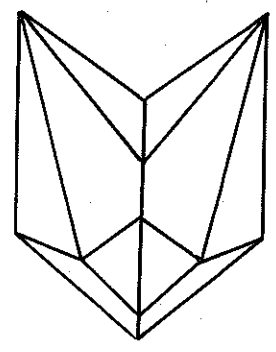
If you see some forms that are similar to *pyrite* crystals, but have a brown or black color, these probably are *limonite* or *goethite* pseudomorphs retaining the crystal form of the original *pyrite*. This is an example of a pseudomorph by alteration, in which there is an exchange of constituents, sulfur for water and oxygen. A nucleus of the original mineral may be found in the center of the altered crystal. Another good example of this is *galena* (PbS) weathering to *anglesite* (PbSO_4) by taking on oxygen, but retaining the form of cubes or octahedrons.

In petrified wood the original wood fiber has been replaced by silica or calcium and magnesium carbonates. The tree probably toppled in a swamp or was buried in a lake. The pores and cavities in the wood were filled with mineral matter in solution in the water and then the silica or calcium and magnesium carbonate took the place of the wood fiber as it disappeared by gradual decomposition. The decomposition of the wood and replacement by mineral matter was simultaneous without any chemical reaction between them. This is an example of a pseudomorph by substitution. *Quartz* after *fluorite* or *calcite* are other examples of substitution.

Phantom or Ghost Crystals

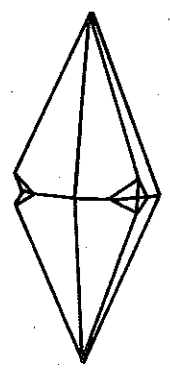
A crystal with an earlier stage of growth outlined in the interior is said to have a "phantom" or "ghost" (plate 2). Usually the faces of the phantom are outlined by a coating or band of foreign material such as clay, *pyrite*, *hematite* or organic matter. These were deposited on the phantom faces from the growth solution and subsequently overgrown. The color and form of the phantom may be the same or different than the later growth. Minerals frequently exhibiting phantom crystals are *calcite*, *quartz*, and *fluorite*.

Contact Twin



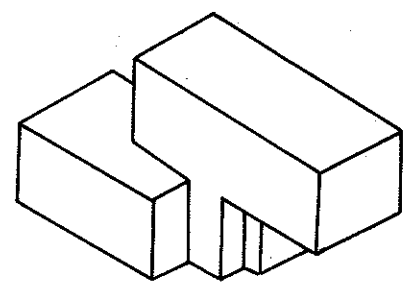
Calcite

Contact Twin



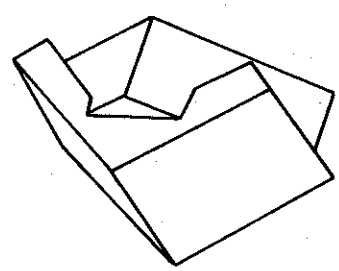
Calcite

Penetration Twin



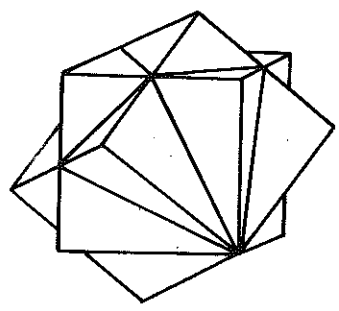
Fluorite

Penetration Twin



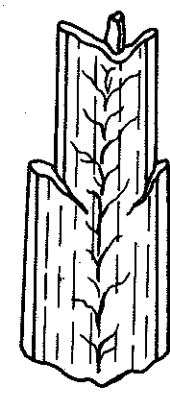
Dolomite

Penetration Twin



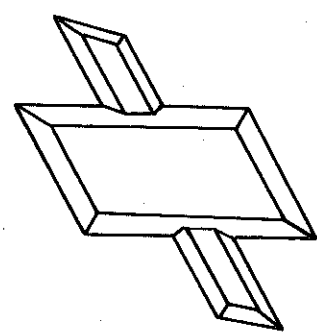
Fluorite

Contact Twin



Gypsum

Penetration Twin



Gypsum

Figure 9. Twin Crystals

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