Saul, LR & Saul RB
1960

MINERAL INFORMATION SERVICE

STATE OF CALIFORNIA DIVISION OF MINES

VOLUME 13 NUMBER 7
JULY 1960

FOSSILS: What they mean and how to collect them

...by L.R. and R.B. Saul

A common type of inquiry received by public agencies in this and other states pertains to fossils or objects thought to be fossils. The practical use of fossils has been explained in this publication (see *Mineral Information Service*, vol. 5, no. 6, pp. 1-3, June 1, 1952). The following information supplements the earlier article, which stressed the practical uses of fossils, by adding a short history of the science of paleontology, by bringing out some of the problems and values of the science as a vocation or avocation, and by pointing out some of the cultural and aesthetic aspects of the study of fossils.

What Are Fossils?

As defined by the noted geologist Amadeus W. Grabau, "Fossils are the remains of animals and plants, or the direct evidence of their former existence, which have been preserved in the rocks of the earth's crust."

Examples of fossil[1] remains can easily be found. Fossils are common in decorative interior limestone, such material having been quarried from deposits of altered limestone which was originally deposited on the ocean floor. Most residents of California have heard of La Brea Pits. Here, large quantities of bones of Pleistocene animals are preserved in asphalt. Many of these bones have been dug out of the pits, cleaned, assembled, mounted as complete skeletons, and put on display in the Los Angeles County Museum. Fossil mollusks (clams and snails) are fairly abundant in rocks deposited in ocean basins which formerly covered large areas of California. Commonly, such deposits contain beds of pebbles and other features which can easily be identified with features one sees along a modern beach. Indeed, many shells similar to those seen scattered about on the present beaches or pulled up on anchors will, in the geologically near future, become fossils.

Some incorrect guesses

Men have always tended to explain the unknown in terms of their own beliefs and prejudices. Herodotus (484?-425 B.C.) was among the first whose written reflections on the origin of fossils are available to us. Aristotle (384-322 B.C.) believed that fossils were organic but that they originated in the rocks. Throughout the Middle Ages the remains of such Pleistocene mammals as cave bears and mammoths were believed to be those of giants, dragons, basilisks, or unicorns. Even in the Renaissance, Voltaire argued that fossil shells were either left by the evaporation in dry seasons of freshwater lakes and rivers or resulted from a superabundance of land snails which multiplied during wet seasons. If the fossil shells could be shown to be of marine types he explained that they had been dropped from the hats of pilgrims on their way from the Holy Land to their homes, or that the shells had been lost from museums or private collections. If the rock around the fossil was so hard that neither of the above explanations would fit he decided that they were not shells at all, but merely shell-like forms, produced by some occult process of nature in the bowels of the earth. In the early 1700's much effort was expended trying to find the men and animals that had perished in the Biblical flood. In 1857, Hugh Miller, a Scottish geologist whose writing and lectures were then popular, wrote, "A century has not yet gone by since all the organic remains on which the science of Paleontology is now founded were regarded as the wrecks of a universal deluge...".

The study of fossils

As Hugh Miller implied, paleontology is the study of the life of the past. From the times of the ancient Greeks, Herodotus and Aristotle, to those of later observers such as Leonardo da Vinci (1451-1519) and Nicholas Steno (1631-1687), gifted individuals understood the nature and significance of fossil bones and shells. The intellectual environment, however, was not favorable to the acceptance of such ideas until the middle 1700's when the work of such men as the great Swedish naturalist Lin-

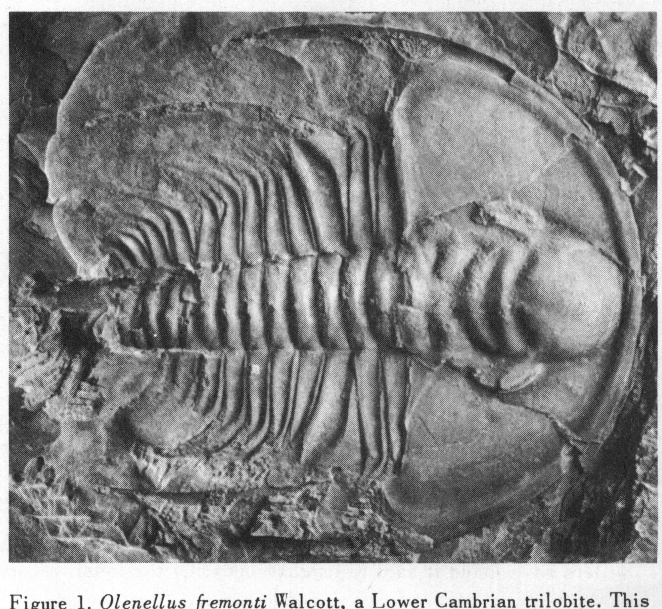

Figure 1. *Olenellus fremonti* Walcott, a Lower Cambrian trilobite. This specimen was found at the south end of the Marble Mountains, San Bernardino County (see figure 3). *Photo courtesy of U.C.L.A. Department of Geology, by Takeo Susuki.*

[1]Generally, workers in the field of paleontology do not include human relics or other evidence of former human activity within the meaning of the term "fossil". If such material is to have real significance, however, its recovery and preservation require the same care as fossil material. State and Federal laws provide against unsystematic (destructive) collecting of such material. (For example, California State Penal Code, section 622.5 and the Federal "Antiquities" Act.)

MINERAL INFORMATION SERVICE

State of California — Edmund G. Brown, *Governor*
Department of Natural Resources — DeWitt Nelson, *Director*
Division of Mines — Ian Campbell, *Chief*

Headquarters office: Ferry Building, San Francisco 11
Branch offices:
312 West 5th St., Room 800, Los Angeles 13
1021 O St., Room A-400, Sacramento 14
Natural Resources Building, Cypress and Lanning Sts.;
mail address, P. O. Box 546, Redding

MINERAL INFORMATION SERVICE is designed to inform the public on the geology and mineral resources of California and on the usefulness of minerals and rocks, and to serve as a news release on mineral discoveries, mining operations, markets, statistics, and new publications. It is issued monthly by the California Division of Mines. Subscription price, January through December, is $1.00.

Other publications of the Division of Mines include the Annual Report of the State Mineralogist, the Bulletin and Special Report series, county reports, and maps. A list of the Division's available publications will be sent upon request. Communications to the Division of Mines, including orders for publications, should be addressed to the headquarters office.

Application for second class mailing privileges pending at San Francisco

naeus resulted in the classification of living plants and animals. This process of ordering or classifying plants and animals, living and fossil, was carried forward for the next hundred years by luminaries such as Georges Cuvier and Alexandre Brongniart. Their classification, like that of Linnaeus, was based upon structural similarities of organisms. Each species was thought to be especially created and the groups into which these naturalists joined them were not considered to be made up of related species but rather of similarly shaped species.

These ideas were bolstered by the incompleteness of the fossil record. It had been observed that a certain stratum contained characteristic fossils that differed from the fossils in higher and lower strata in the same section and that other strata were apparently devoid of fossils. Thus it was reasoned that each assemblage of animals or plants represented a resurgence of life which was destroyed by a catastrophe and replaced by another, unrelated group. This meshed well with the catastrophic approach to geology which then was popular.

The Geologic Time Scale

Despite missing pages

The world of the catastrophists was envisioned as one of large scale upheavals and mass slaughter of plants and animals. In the middle nineteenth century, thanks mainly to the observations and ideas of three men, James Hutton, Sir Charles Lyell, and Charles Darwin, belief in the gradual, evolutionary processes for the sculpturing of the earth and the development of life began to be more and more strongly supported.

Hutton argued that, given sufficient time, the processes now at work could have produced all of the structures observed in the rocks. This came to be known as Uniformitarianism, succintly described by the phase "the present is the key to the past."

Charles Lyell took Hutton's ideas, added many of his own thoughts and observations and published a three-volume masterpiece, "Principles of Geology" (1830-1833), which subsequent writers have found it hard to improve upon. Of the fossil record he says:

"As to the want of completeness in the fossiliferous series, which may be said to be almost universal, we have only to reflect on what has been already said of the laws governing sedimentary deposition, and those which give rise to fluctuations in the animate world, to be convinced that a very rare combination of circumstances can alone give rise to such a superposition and preservation of strata as will bear testimony to the gradual passage from one state of organic life to another."

Charles Darwin is reported to have had Lyell's first volume in his luggage when he boarded the *H.M.S. Beagle* for his famous voyage around the world. No name is more closely linked in the public mind to the principle of evolution than that of Darwin. His work, "On the Origin of Species by Means of Natural Selection", published in 1859, is still so basic as to be required reading for students of zoology, paleontology, and geology.

Although there are still "missing pages" in the record of past life, most workers agree that the overall picture is one of gradual change. As more fossil material is collected, transitional forms are found and thereby demonstrate a connection between types for which, formerly, a relationship only had been suggested.

Collecting Fossils

The importance of being orderly

Some people will collect anything they can carry. Quite by chance, such items are sometimes useful, serving, perhaps, as door stops, ash trays, fire place stones, or something to strike matches on. Between this miscellany and the order of a museum there lies a middle ground which includes most collections.

As anyone who has made a hobby of collecting knows, some some sort of order is desirable. Not only does this help to keep track of what has been acquired and what the collector wishes to acquire, but it adds to the interest of the collection. Whether it is a long-term hobby or a short-term scout project, collecting fossils will be more fun and more educational if the specimens are arranged to show either the past environment of an area or relationships between the animal remains in the collection.

ERAS		PERIODS OR EPOCHS	YEARS AGO AT BEGINNING	APPROXIMATE DURATION
CENOZOIC		Pleistocene Epoch	1,000,000	1,000,000–
	TERTIARY PERIOD	Pliocene Epoch	9,000,000	8,000,000
		Miocene Epoch	28,000,000	19,000,000
		Oligocene Epoch	38,000,000	10,000,000
		Eocene Epoch	58,000,000	20,000,000
		Paleocene Epoch	75,000,000	17,000,000
MESOZOIC		Cretaceous Period	130,000,000	55,000,000
		Jurassic Period	155,000,000	25,000,000
		Triassic Period	185,000,000	30,000,000
PALEOZOIC		Permian Period	210,000,000	25,000,000
	CARBONIFEROUS	Pennsylvanian Period	235,000,000	25,000,000
		Mississippian Period	265,000,000	30,000,000
		Devonian Period	320,000,000	55,000,000
		Silurian Period	360,000,000	40,000,000
		Ordovician Period	440,000,000	80,000,000
		Cambrian Period	520,000,000	80,000,000
PRECAMBRIAN				

Figure 2. Geologic time scale.

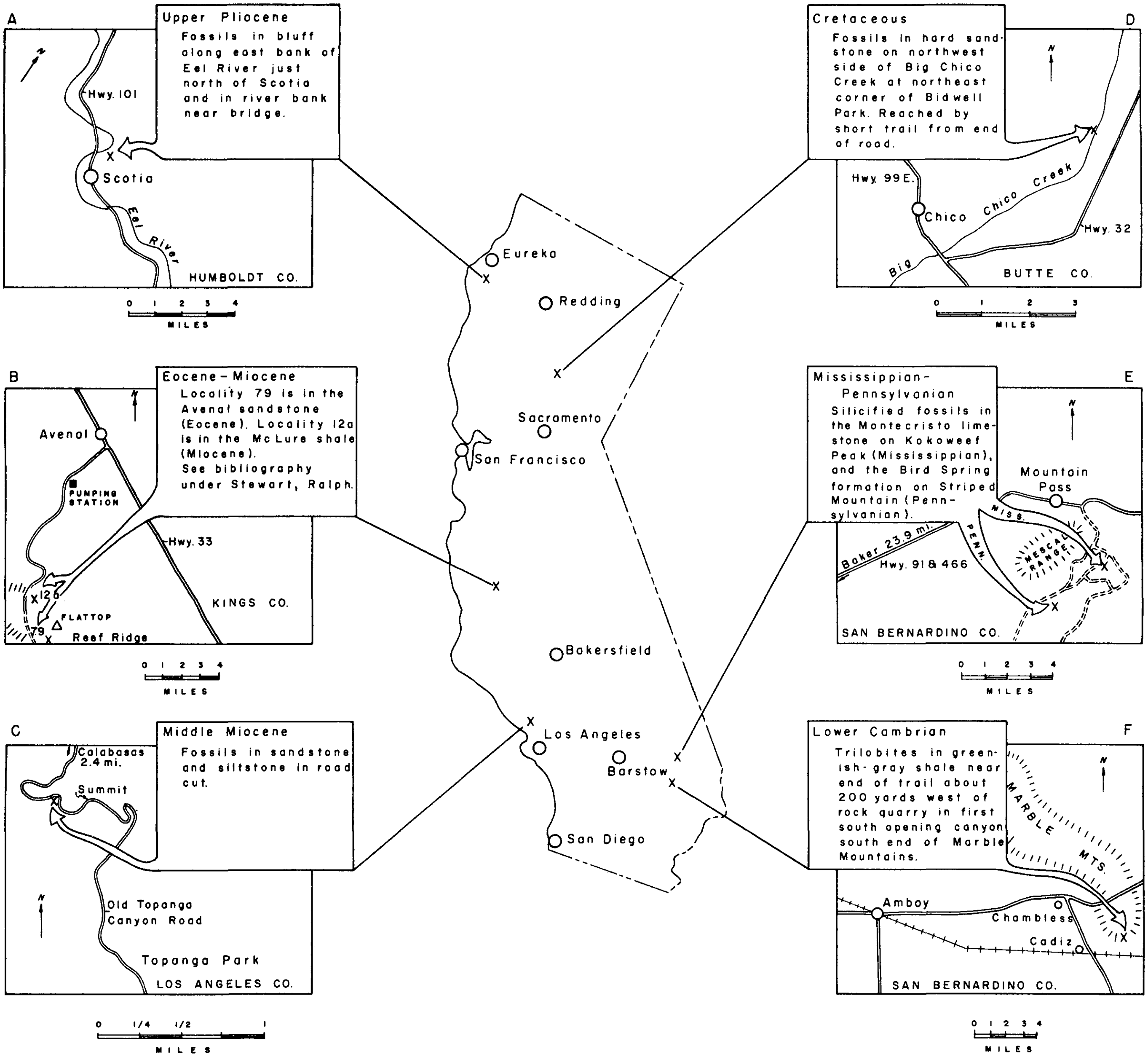

Figure 3. The localities shown in the above maps yield fossils of varied types from widely spaced intervals in time.

A. The moderately well-preserved shells of a marine invertebrate fauna are contained in a succession of shale, siltstone, and sandstone beds called the Wildcat series. The indicated locality is one of many in the Scotia-Eureka area. For references see California Division of Mines Special Report 52, p. 22-23.

B. These localities are on Reef Ridge. The numbers are the same as those used by Stewart in U.S. Geological Survey Professional Paper 205-C. Stewart's geologic map shows many other localities along the same ridge and may be used to check formation names and ages.

C. This area yields a moderately well-preserved middle Miocene invertebrate marine fauna. A diversity of gastropods (snails) and pelecypods (clams) constitute an assemblage characteristic of the Topanga formation.

D. This is an old and famous locality. The fossils are in a cliff of hard sandstone a few hundred feet upstream from an old corral at the end of the road. Collecting is not as easy as it used to be here, and the collector may find it advantageous to push on upstream. The sandstone of this, the Chico formation, is exposed for about 6 miles to the northeast along Big Chico Creek. The fossils generally are found in hard, pod-shaped concretions. Much of this is private land however, and in the summer there is a fire hazard.

E. Here is a chance to collect some fossil corals and brachiopods. This material has been replaced by silica and can be removed from its limestone matrix with dilute hydrochloric acid.

F. This is a locality where, with a little patience, good specimens of at least two genera of trilobites are to be found. The specimen shown in figure 1 was collected here.

Take the road east along the railroad from Cadiz to where it crosses the railroad track, then take a dirt road north to the quarry.

Many collections which began as enjoyable hobbies also have come to be of real scientific value mainly because the collector was careful to note and record the locality and the date the fossil was collected. A well-organized collection has led many an amateur to observe some hitherto overlooked and possibly important fact.

Where are fossils found?

Fossils characteristic of every major subdivision of the geologic column (as shown in figure 2) can be collected in California. However, some knowledge of where certain types of fossils are apt to be found is desirable.

The collector wishing to collect horse bones, for example, will usually have to search in a few scattered areas underlain by nonmarine sediments of Eocene or later age. His search for the remains of invertebrate, marine organisms of Paleozoic age will probably be most successful in the desert area east and southeast of the Sierra Nevada. For fossils of animals more closely related to present-day marine faunas, the collector will search west and southwest of the Sierra Nevada where rocks formed in Mesozoic and Cenozoic marine basins are now exposed around the fringes of the Central Valley and in the Coast Ranges. The beginner will soon discover that areas such as the high Sierra Nevada, or most parts of San Bernardino Mountains are poor places to find fossils. Obviously, life has existed at such sites in the past but subsequent geologic processes involving heat, pressure, weathering, and erosion acting together or separately have destroyed most of the record. Figure 3 shows a few of the many localities in California where a fossil collector may get a start.

The collector should learn to use the library. Reports on the geology and paleontology of many parts of the state have been published as Professional Papers and Bulletins by the U.S. Geological Survey and in the Journal, Bulletins, and Special Reports of the California Division of Mines. The University of California, Stanford University, the California Academy of Sciences, and the San Diego Society of Natural History have published many useful reports. Although these are technical reports, fossil localities are commonly shown on the maps and, in many, fossil specimens are pictured. In addition, various professional journals contain reports on paleontology and related fields.

Whether it is planned to collect fossils of all types and ages or specialize on one type or age, each collector will refer to the work of others and can soon learn to ferret out the information pertaining to his own interest. One starting point might be California Division of Mines Special Report 52, *"Index to geologic maps of California to December 31, 1956"*. This contains a list of references which are keyed to maps. These references will help the collector to determine what types of rocks and ages of rocks have been described in a given area.

One should be sure to respect the boundaries of private land and restricted areas where he collects. As a rule permission to collect can be obtained by local inquiry but in some areas held by large ranches, corporations, etc., formal permission is required, especially for large groups.

Tools

The tools used are a matter of common sense. Sand or silt will yield most readily to shovels, hoes, trowels and screens. Hard rock, commonly described in the literature as well-indurated or concretionary, will require sledges, hammers, chisels and crowbars. Gloves are recommended. Normal caution should be used in turning over rocks or in cutting into burrows and fissures where snakes, scorpions and spiders are apt to hide.

One of the advantages of finding localities through the literature is the fore-knowledge it affords of the type of rock in which the fossils will be found. The prospect of visiting several localities in a day may require that a diverse array of equipment be carried in a car or jeep, but where it is necessary to walk a mile or more to reach a specific locality the collector does not want to carry useless tools.

Figure 4. Collecting fossils. Note the convenience of the war-surplus ammunition bag. Hammers, chisels, sample bags and wrapping material are in the front pocket.

Some material will require careful treatment at the collecting site. Frail bones may have to be shellacked and reinforced with plaster before removal. (For a more complete description of methods of collecting vertebrate remains see Stirton, *Time, Life, and Man*, p. 34-37). When well-preserved fossils are found in hard rock it is good practice to bring blocks of the material home. The individual specimens will thereby be protected by their matrix during transportation and can later be worked out more carefully than time permits in the field. A variety of knapsacks may be used to carry material from the field. Heavy paper bags are useful. Locality data may be written on them or placed inside on a separate label (figure 4). Newspapers or other soft paper goods are valuable for wrapping frail specimens.

If one really wants the specimen, the time spent on careful collecting is very worthwhile. After all, the fossil has been preserved for thousands or millions of years; why destroy it in 5 minutes?

Removal of matrix

The nature of the matrix often suggests whether a fossil can be cleaned by washing in water, in water dissolved chemicals or simply by careful abrasion of the adhering particles. An assortment of chisels and hammers is desirable for rough work. Rock trimmers of the arbor-press type are useful if available. Museums having power equipment commonly employ dental tools or vibrating-tip engraving tools to remove obscuring silt and sand. Mollusk shells, which commonly are frail and may be further weakened by recrystallization may require extreme care.

Specimens embedded in siltstone or mudstone are sometimes cleaned by soaking in water and scrubbing with tooth brushes or small hand brushes. The process is hastened by adding detergents or washing soda and will be further enhanced by gentle boiling. Such simple treatment is not effective for a matrix thoroughly cemented by iron oxides, calcium carbonate, or silica.

Some fossils are replaced by silica. When such fossils are found in limestone or limy sediments they can be etched free of the matrix with dilute hydrochloric acid. For delicate or only partially silicified specimens a solution of weak, slow-acting acetic acid is used. Formic acid has recently been used to etch fossil insects of Miocene age from calcareous nodules found in the Calico Mountains near Yermo, California (see U.S. Geological Survey Professional Paper 294-G).

High-frequency vibrations introduced into a liquid-filled tank have been employed to clean paleontological material. This results in a lowering of surface tension on the surface of the adhering particles and accelerates chemical and physical breakdown of the adherence bonds. Such devices have proved most useful in cleaning extremely small fossils (microfossils) but they are also effective with larger fossils when the matrix is fine-grained and is compacted rather than cemented. The cost and specialized uses of such devices makes them impractical tools for the average collector.

Another method of breaking down the well-compacted, fine-grained matrices involves the use of a solvent such as gasoline, kerosene, or alcohol. The fossiliferous material is thoroughly saturated with the solvent, then dried. During this process, some shales and mudstones will fall apart; others require boiling with water and a wetting agent.

Preservation

After cleaning, some fossils are ready to be identified and studied, stored, or exhibited, but many require some further treatment. Very fragile, porous specimens may be soaked in a thin alvar-acetone solution. Somewhat sturdier specimens can be dipped in or painted with shellac well thinned by alcohol. This makes fragile material more resilient and provides a more dust-free surface. The most common technique of repairing fossils is that of simply gluing the parts of a broken specimen back together. A fast-drying amberoid or duco-type glue is suitable.

Identification

What is it?

Proper identification is time consuming. If the material is without locality data it is hardly worth spending the time to identify it. Anyone planning to make a hobby of fossils should become acquainted with the literature in which the name assigned to the fossil can be discovered. The same literature recommended for use in finding field localities also will prove useful in identification. Some such works are included in the bibliography along with two basic text-books on paleontology in which scientific terms are defined. A basic text-book also will aid in determining to which group a fossil belongs. Identifications will become increasingly accurate with experience.

Specimens that have been described and illustrated are preserved in the collections of museums and universities. These research collections are not always open to the general public, but are often made available to anyone whose knowledge and interest warrant it and whose project requires it. Usually the comparison of one's own material with the research collections of such institutions provides a final check on identification.

Not all fossils have been described, and there is always the possibility of discovering something new. The description of a new species requires much more checking and comparing than does the identification of a species already described. Rules governing the description of a new form can be found in "Procedures in Taxonomy" (see bibliography under Schenck and McMasters).

A look at names

Before Linnaeus there was no standard nomenclature. Often the names devised by naturalists were really brief Latin descriptions. However brief, though, descriptions make cumbersome names, and naturalists found the binary or binominal system of Linnaeus much more concise. From this has evolved the present binominal system, based on the rules of the International Commission on Zoological Nomenclature. Zoological names usually consist of two italicized names plus the author's name.

Submortoniceras	*chicoensis*	(Trask)
generic name	specific name	name of the author who first described the fossil.

The *generic name* always begins with a capital. It is used to refer to species which have certain characteristics in common. For each genus there is a "type species", that is, a designated species which exhibits these characteristics. Some genera have had only one species thus far assigned to them; but most genera consist of a number of species which are considered to be related.

The *specific name* usually is not capitalized. A species is based upon the characters exhibited by a particular individual specimen, the holotype. All specimens that can be shown to be sufficiently like the holotype will be included in that species. The species may be moved from one genus to another but the specific name remains the same. In the above example the name *chicoensis* was first applied to the species by J.B. Trask in 1856. He called it *Ammonites chicoensis;* that is, an ammonite from Chico (*-ensis*, is a suffix, meaning place). As the classification of ammonites has been refined, the species *chicoensis* Trask has been moved from genus to genus, becoming succes-brackets [*Ammonites*]; in paleontologic literature such brackets commonly indicate a name used in the past but not now considered appropriate by a given worker.

The *author's name* is included to make doubly sure that we are all considering the same group of animals. This will always be the name of the person who first described the species. It is common practice to put the author's name in parenthesis if the species has been removed from the genus in which it was originally described. This is a signal to anyone looking up this species that he must search under more than one generic name.

Storage

Keep it clean

The problem of storage is an initial concern solved by each collector in his own way, but certain basic requirements exist. Cases should afford ready access and provide some measure of protection from dust. Tiers of closed-in drawers are a common mode of storage. Simple, open racks into which trays may be slid are inexpensive but afford less protection. Glass cases are an attractive means of displaying specimens; however, they generally require more space and are more expensive. Figure 5 shows a common type of storage.

Keep a record

Labels should serve not only to identify fossils but also to tie them to a carefully kept record. This should make inadvertent mixing correctable.

In keeping a record, one has a wide choice of methods. A card file or catalog will serve the purpose and it may prove advantageous to use a combination of the two to relate separate systems of data. For example, an arbitrary series of numbers might be assigned to localities and entered consecutively in a catalog of locality descriptions. In contrast, individual specimens will probably be stored according to biological group and/or according to age. To relate or unify these systems the locality numbers and possibly a brief statement of locality should be entered on the file cards and labels. In addition the locality number should be placed on each specimen so that it will always have an identifying mark should the specimen ever be misplaced.

Marking fossils is simple. Small dots or punchings of paper are commonly used, the locality number being printed thereon with india ink. Some collectors prefer small spots of paint. One

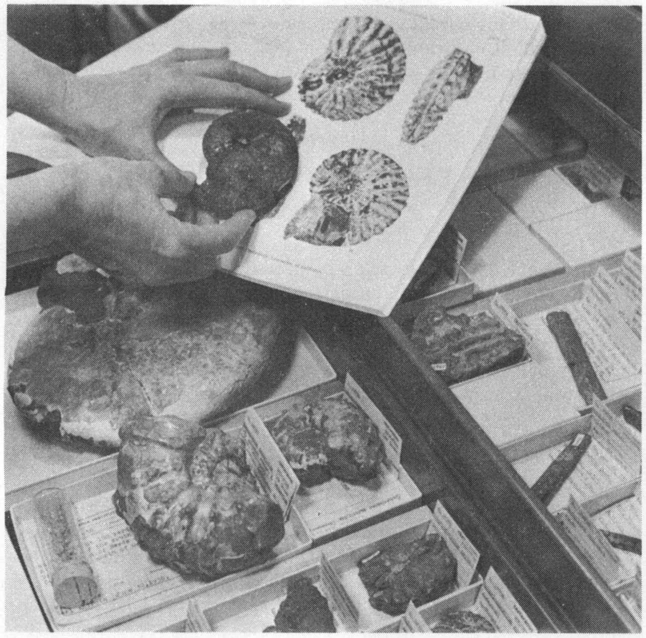

Figure 5. A typical mode of storing fossils. In this example, three flat trays are accommodated in a single drawer. Note the clearly visible, numbered labels and the correspondingly numbered labels attached to the specimens. The less visible parts of the labels carry locality data. A specimen of *Submortoniceras chicoensis* (Trask) is being compared with a photograph of a specimen of the same species in one of the volumes of Upper Cretaceous Ammonites of California, by Tatsuro Matsumoto.

such method employs an initial coat of white lacquer on which the number is printed. When dry, number and base coat are covered with a final coat of clear lacquer thus preserving the number from moisture or abrasion. Colored paper or paint may be used to indicate age groupings and thereby give this identifying feature a dual value.

When attaching permanent labels of any kind to specimens important features should not be covered. Much of the permanent value of a fossil lies in the ease with which it can be used for comparison with other specimens.

Annotated Bibliography

The following list of references is by no means complete. It does, however, contain some "indispensable" items and a fair sampling of the various types of literature used by paleontologists and geologists.

Arnold, Ralph, 1906, Tertiary and Quaternary Pectens of California. U.S. Geological Survey Professional Paper 47. A report which briefly outlines the Tertiary and Pleistocene formations of California, their localities, the species of *Pecten* found in them, and their typical fauna as known to that date. It includes descriptions and illustrations of all known Tertiary, Pleistocene and Recent Pectens of the west coast of North America. A map of fossil localities is included.

Boy Scouts of America, Geology Merit Badge pamphlet, 1953, 84 pp. One chapter is devoted to a short, simplified, and accurate outline of invertebrate, vertebrate, and plant fossils.

California Division of Mines, 1952, Use of fossils in geologic exploration. Mineral Information Service, June 1952, 3 pp. (reprint). Free upon request. A brief discussion of the principles used in paleontology, and the use of fossils in geology and industry. Contains sketches of nine California index fossils, and a chart of the geologic time scale.

Camp, Chas. L., and Hanna, G.D., 1937, Methods in paleontology. Univ. Calif. Press, Berkeley, 153 pp. A detailed explanation of field and laboratory methods used to recover vertebrate fossils (by Camp) and invertebrate fossils (by Hanna).

Camp, Chas. L., 1952, Earth Song—A prologue to history. Univ. Calif. Press, Berkeley, 127 pp. with pencil sketches. A story of life on earth from simple sea forms to man. Written in an easy narrative style, poetic in places. Excellent sketches help make this a beautiful book.

Colbert, Edwin H., 1955, Evolution of the Vertebrates. Wiley and Sons, N.Y., 480 pp. Fish, amphibians, reptiles (dinosaurs), birds, and mammals.

Casanova, Richard, 1957, An illustrated guide to fossil collecting, (ed. by Vinson Brown). Naturegraph Co., San Martin, Calif., 80 pp. A non-technical short book devoted mostly to invertebrates. Contains a state-by-state discussion of collecting localities.

Collinson, Chas. W., 1956, Guide for beginning fossil hunters. Illinois State Geological Survey, Educational Series no. 4, Urbana, Ill., 35 pp. A non-technical, abundantly illustrated pamphlet devoted mostly to invertebrates. Not restricted to Illinois' fossils.

Darwin, Charles, 1859, On the origin of species by means of natural selection: available in various editions. This book remains one of the definitive, basic scientific works. It is a good example of the application of the scientific method to the interrelatedness of living organisms.

Dickerson, Roy E., 1916, Stratigraphy and fauna of the Tejon Eocene of California. Univ. California, Dept. Geology Bull., vol. 9, no. 17, pp. 363-524, plates 36-46. An attempt to help geologists and paleontologists better to recognize beds containing a characteristic fauna.

Dunbar, Carl O., 1949, Historical Geology. John Wiley and Sons, New York, 567 pp. A standard historical geology text.

Faul, Henry, 1960, Geologic time scale. Geol. Soc. America Bull., vol. 71, p. 637-644. A brief review of methods and available data for the determination of geologic dates. The use of fossil evidence as a necessary check on radiogenic age determinations is well illustrated.

Grant, U.S., and Gale, H.R., 1931, Catalogue of the marine Pliocene and Pleistocene Mollusca of California and adjacent regions. San Diego Soc. Nat. Hist., Memoirs, vol. 1, 1036 pp., 32 plates. A catalogue of the species and varieties of marine mollusks occurring in the Pliocene and Pleistocene deposits of California and a summary of the relations of the beds in which they are found. There are notes on morphology, classification, and nomenclature.

Grant, U.S., and Hertlein, L.G., 1938, The West American Cenozoic Echinoidea. Univ. California Los Angeles Pubs. in Math. and Phys. Sci., vol. 2, 226 pp. 30 plates. This report stresses the usefulness of fossil echinoids, reviews their nomenclature, catalogues them, records new forms, and reports new occurrences.

Jahns, R.H., and others, 1954, Geology of southern California—Historical geology. California Div. Mines Bull. 170, Chap. 3, 83 pp.

Jenkins, O.P., and others, 1943, Geologic formations and economic development of the oil and gas fields of Calif. California Div. Mines Bull. 118, 773 pp. (out of print). Contains 9 chapters on fossils, one being of particular interest to fossil collectors.

Jenkins, O.P., and others, 1951, Geologic guidebook of the San Francisco Bay Counties (history, landscape, geology, fossils, minerals, industry, and routes to travel). California Div. Mines Bull. 154, 392 pp. plus maps. Contains 3 chapters on fossils.

Keep, Josiah and Bailey, J.L., 1935, West Coast shells (A description in familiar terms of the principal marine, freshwater, and land mollusks of the U.S., British Columbia, and Alaska found west of the Sierra). Stanford Univ. Press, Calif., 350 pp. An excellent book on recent shells (conchology) written in narrative form, with scientific names and format. Detailed ink sketches.

Kummell, Bernard, 1953, American Triassic coiled nautiloids. U.S. Geological Survey Professional Paper 250. A discussion and description of all North American species of Triassic nautiloids and a review of their status and phylogenetic relationships involving such late Paleozoic families as are deemed useful.

Ley, Willy, 1949, Dragons in amber. the Viking Press, New York, 328 pp. A book by a well-informed and entertaining author, replete with historic, geologic, and paleontologic highlights.

Life Magazine, 1955, The world we live in. Time Inc., 394 pp. A superbly illustrated survey of the evolution of all natural history with sufficient text to explain the detailed drawings. Two chapters on life of the past.

Lyell, Charles, 1830, Principles of geology. The first full statement of essentially modern geological concepts written in a literate and enjoyable style. In later edition (e.g. 1875) the effects of Darwin's findings are evident.

Matsumoto, Tatsuro, 1959-60, Upper Cretaceous Ammonites of California. Kyushu Univ., Memoirs of the faculty of Science, Series D, Geology, vol. 8, no. 4, and special vols. 1 and 2. Careful, well illustrated work on one of the most interesting groups of fossil mollusks. It demonstrates the truly international nature of paleontology.

Miller, Hugh, 1857, The testimony of the rocks. The subtitle of this work, "Geology in its bearings on the two theologies, natural and revealed", suggests, as is true, that this book is transitional from the old theologically oriented geology to that of uniformitarianism.

Moore, R.G., Lalicker, C.G., Fischer, A.G., 1952, Invertebrate fossils. McGraw-Hill Co., 766 pp. A standard American college textbook on systematic paleontology. Outstanding for its bold black and white drawings, completely labeled, that do not rely on captions for understanding.

Mortensen, Theodor, 1928-51, A monograph of the echinoidea. (5 vols.). C.A. Reitzel, Copenhagen; H. Milford, Oxford Univ. Press, London. Discusses all echinoids (sea urchins) then known, both living and fossil.

Palmer, Allison R., 1957, Miocene arthropods from the Mojave Desert California. U.S. Geological Survey Professional Paper 294-G. This paper is of interest not only because insects are rare in the fossil record but because of the type of preservation and the techniques used to recover the specimens.

Resser, Charles E., 1928, Cambrian fossils from the Mojave Desert. Smithsonian Miscellaneous Collections, vol. 81, no. 2, 14 pp. 3 places. This is a typical short contribution to the growing fund of paleontologic knowledge.

Ricketts, E.F., and Calvin, J., 1939, Between Pacific tides. Stanford, California, 502 pp. This book stresses the natural assemblages of marine animals along the west coast and will give the fossil collector an appreciation of environmental groupings sometimes evident in the fossil record.

Schenck, E.T., and McMasters, J.H., 1956, Procedure in Taxonomy. Stanford Univ. Press, Stanford, California, 119 pp. This useful book will give the collector a more thorough understanding of nomenclatural rules than space allows in the above article. It is a manual of procedure.

Schenck, H.G., 1936, Nuculid bivalves of the genus Acila. Geol. Soc. America, Special Papers no. 4, 149 pp., 18 plates. An example of a study of a genus.

Schenck, H.G., and Keen, A.M., 1950, Calif. fossils for the field geologist. Stanford Univ. Press, Calif., 88 pp. plus 56 plates. No text. The large detailed photos and diagrams are to be matched against fossils collected in the field and thereby permit identification of the fossils by genus and species.

Shell Oil Co., 1956, Let's collect shells. 50 W. 50th St., New York 20, 13 pp. (free upon request). An entertaining pamphlet for the city-dwelling sea-shore collectors of recent shells. Brief description of the shell, names, and equipment.

Shrock, R.R., and Twenhofel, W.H., 1953, Principles of invertebrate paleontology. McGraw-Hill Co., N.Y., 815 pp. A standard American college textbook on systematic paleontology. This is a revised and enlarged edition of a similar book by the same authors in 1935 which bespeaks of its eminence.

Stewart, Ralph, 1946, Geology of Reef Ridge, Coalinga district California. U.S. Geological Survey Professional Paper. 205-C. A paper on the area southwest of Kettleman Hills—the Reef Ridge. A source of background for those planning to collect in the area, it has locality data and good illustrations of fossils.

Stirton, R.A., 1958, Time, life and man. John Wiley and Sons, New York, 558 pp. A basic textbook of paleontology containing good introductory material including a chapter on methods. This author traces the development of life through time in a well illustrated manner. His concluding chapters deal with foraminifera (microfossils) and the evolution of various forms of life.

Stock, Chester, 1949, Rancho La Brea, (A record of Pleistocene life in Calif.) 4th ed. Los Angeles County Museum, 81 pp.

Strand, R.G., Koenig, J.B., and Jennings, C.W., 1956, Index to geologic maps of California to December 31, 1956. California Div. Mines Special Rept. 52. This report is a means of determining the nature of geologic work completed in any given area in the state to the given date. References are keyed to a series of index maps upon which the outlines of the areas covered are shown.

Woodring, W.P., and Bramlette, M.N., 1950, Geology and paleontology of the Santa Maria district California: U.S. Geological Survey Professional Paper 222. An excellent example of its type of publication. The fossil material is well illustrated and there is an interesting section titled, "Environment suggested by fossils".

Woodring, W.P., Stewart, R., and Richards, R.W., 1940, Geology of the Kettleman Hills oil field California. U.S. Geological Survey Professional Paper 195. A description of the geology and paleontology of one of California's oil fields. It demonstrates the use of fossils in solving practical problems.

RECOVERY OF ALUMINA FROM ANORTHOSITE

One of the current cooperative research projects jointly sponsored by the California Division of Mines and the U. S. Bureau of Mines involves an attempt to develop a commercial process for extraction of alumina from California anorthosite, an igneous rock rich in feldspar. Large resources of this type of aluminum-rich rock occur in southern California, but commercially feasible methods of recovery of alumina from them have not been developed.

The lime-soda sinter process, extensively studied by the Bureau of Mines, is being applied in this research. Current investigation by the Bureau is geared to learning the chemistry of the lime-soda sinter process in greater detail than is presently known.

A 1-ton sample of anorthosite from the San Gabriel Mountains was taken from a roadcut exposure on the south side of the mountain summit. The location was in the general area of T. 3 N., R. 12 W. The analysis of the sample was:

Al_2O_3	27.8%	K_2O	0.29%
SiO_2	52.6%	MgO	.40%
CaO	9.5%	TiO_2	.25%
Fe_2O_3	1.9%	L.O.I.	
Na_2O	5.8%	1000°C	.72%

A sample from another area of the deposit will be taken later this spring.

Basically, the lime-soda sinter process for recovering alumina from aluminum silicates involves mixing the ore with sufficient limestone and soda ash so that upon sintering the mixture a dicalcium silicate and sodium aluminate will be formed. The sodium aluminate is soluble, while the dicalcium silicate is insoluble in causticized solutions. After separating the leach liquor from the insoluble residue, the alumina may be recovered by precipitation.

In practice, the operation of the process is more complicated, and additional operational steps and techniques are necessary. These are briefly as follows:

All of the components—anorthosite, limestone, and soda ash—must be finely ground to achieve intimate mixing. The components must be mixed in such ratio that the final sinter will carry a mol ratio of CaO to SiO_2 of about 2.0 and a mol ratio of Na_2O to Al_2O_3 of about 1.0. Some means of control to assure uniform sintering is desirable.

The mixture may then be sintered in a rotary kiln in the same manner used to prepare cement clinkers. However, up-draft sintering on a traveling grate appears to promise a better job than the rotary kiln. It has not been tried commercially for the lime-soda sinter, but a laboratory up-draft sintering hearth produces an excellent sinter. When this type of hearth is used, crushed

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF MINES
FERRY BUILDING
SAN FRANCISCO 11, CALIF.

RETURN POSTAGE GUARANTEED
Form 3547 Requested

APPLICATION FOR 2ND CLASS
MAIL PRIVILEGE IS PENDING
AT SAN FRANCISCO

petroleum coke is added to the mixture, prior to sintering, to act as a fuel. Sintering temperatures are controlled to the range of 1350°C to 1400°C.

The sinter is ground to about 100 mesh and mixed with the leach liquor in a ratio of about 2 milliliters of liquor per gram of sinter. An optimum leach liquor should be composed of about equal equivalents of NaOH and Na_2CO_3, and the total Na_2O content should be about 50 grams per liter. This composition is subject to wide variations in practice.

The best temperature for leaching is about 70°C, and contact time of half an hour is generally sufficient. Immediate separation of liquor from the leached solid is desirable. Serious troubles can occur at this point because poorly made sinters tend to gel or set. The lime-soda sinter composition is not far removed from the area in a ternary system representing Portland cement compositions. Therefore, cement characteristics should be expected in the lime-soda sinter, and such is actually the case where leach slurries gel on standing. To minimize such occurrences, sintering techniques must be carefully controlled.

Leaching also takes a small amount of silica into solution. The pregnant leach liquors will carry about 3 grams of SiO_2 per liter. This silica must be removed before precipitating the alumina, for alumina specifications generally require that the SiO_2 content be less than 0.03 percent. The SiO_2 is removed from leach liquor by adding about 6 grams per liter of lime and autoclaving for one hour at 200 p. s.i.g. This treatment drops the SiO_2 content of the liquor to less than 0.1 gram per liter.

Alumina is recovered from the purified leach liquor by treating the liquors with a gas mixture of CO_2 and air. In a commercial operation, the gas mixture would be flue gases from a furnace operation in the plant. The alumina recovered is pure alumina trihydrate ($Al_2O_3 \cdot 3H_2O$). Calcining the trihydrate gives the alpha alumina of commerce.

Early tests, using the foregoing laboratory techniques, have demonstrated that an alumina recovery of 90 percent is possible.

NEW MINING LAW...

Public Law 86-390, approved March 18, 1960, amends the United States mining laws to permit millsite locations in connection with placer mining claims. Prior to the passage of this law, millsite claims could only be obtained for use in connection with lode mining claims.

Section 2337 of the Revised Statutes of the United States (30 U.S.C. 42) is amended (1) by adding "**(a)**" after "**SEC. 2337.**", and (2) by adding at the end thereof a new subsection as follows:

"(b) Where nonmineral land is needed by the proprietor of a placer claim for mining, milling, processing, beneficiation, or other operations in connection with such claim and is used or occupied by the proprietor for such purposes, such land may be included in an application for a patent for such claim, and may be patented therewith subject to the same requirements as to survey and notice as are applicable to placers. No location made of such nonmineral land shall exceed five acres and payment for the same shall be made at the rate applicable to placer claims which do not include a vein or lode."

LOCATING GUANO DEPOSITS—a correction

The April 1960 issue of *Mineral Information Service* carried an article on commercial guano. This article contained an error in describing the manner in which one could gain legal right to a bat guano deposit. Such deposits are not subject to location, but may be leased as phosphate deposits from the United States Government under the authority of the Mineral Leasing Act of February 25, 1920 (30 U.S.C. 211-214) and the regulations of the Secretary of the Interior (43 CFR 196). We have been further advised that where the composting action has gone on for thousands of years, cave niter results, as in the small caves in the rhyolite in northern Nevada. Such deposits may be leased as sodium-bearing deposits.

NEW U.S.G.S. PUBLICATION

Results of a detailed study of the foraminifera of the Monterey shale and the Puente formation in the Santa Ana Mountains and San Juan Capistrano area, Orange County, in southern California, are described in a new publication by the Geological Survey.

The rocks in which the foraminifera (tiny middle and late Miocene marine animals with calcareous shells) occur represent an eastward extension of strata which are prolific oil producers in parts of the Los Angeles basin.

Studies such as this make possible the correlation of rock units, since various species of foraminifera reflect the geologic age of the bed in which they are present.

The Geological Survey carried on oil and gas investigations in and near the Santa Ana Mountains from 1945 to 1955. Shells of hundreds of foraminifera from the area were collected and examined. The localities sampled are shown on maps accompanying the report and are described in the text. The maps also show areas of rock outcrops and the locations of test wells and core holes that were used in preparing the structure section and that were sampled for foraminifera. A list of these wells and core holes is given.

Also included in the report are charts showing distribution of the foraminifera and the geologic ranges of the more important and abundant species, and systematic descriptions and photographs of foraminifera of the Monterey shale and Puente formation.

Foraminifera of the Monterey shale and Puente formation, Santa Ana Mountains and San Juan Capistrano area, California, by Patsy Beckstead Smith, has been published as Geological Survey Professional Paper 294-M. Copies can be purchased from the Superintendent of Documents, United States Government Printing Office, Washington 25, D.C., for 40 cents each. The report is also available for over-the-counter sale (but not by mail) at Geological Survey offices at 1031 Bartlett Building, Los Angeles, and 232 Appraisers Building, San Francisco, California. It is not sold by the Division of Mines.

❋ ❋ ❋ ❋ ❋

If you are touring the historic Mother Lode country this vacation, let our Bulletin 141, *Geologic Guidebook along Highway 49*, be your personal guide. On sale at any Division of Mines office for $1.50 plus tax.

(B–a)

77598 650 7-68 5M