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# Syllabus of Historical Geology

BY

PROFESSOR A. W. GRABAU



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# COLUMBIA UNIVERSITY

DEPARTMENT OF GEOLOGY

## Syllabus of Historical Geology

BY

Professor A. W. GRABAU

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**Definition:** Historical Geology treats of the history of the earth and its inhabitants from the beginning to the present time.

**Three Aspects:** I Stratigraphy: History of Rocky frame work—chiefly of the stratified rocks or Strata. II Palaeontology: History of life of the earth. III Physiography: History of development of surface features.

1 **STRATIGRAPHY:** Represented by maps and sections. Sections are:

1 Natural or cross-sections giving succession and structure.

2 Columnar Sections—giving succession and thickness of rocks only.

3 Ideal sections—restoring former conditions.

## TABLE OF GEOLOGIC FORMATIONS.

### Psychozoic or Quaternary.

Holocenic or recent

Pleistocenic

### Cenozoic or Tertiary.

Pliocenic

Miocenic

Oligocenic

Eocenic

### Mesozoic or Secondary.

Cretacic

Comanchic

Jurassic

Triassic

### Palaeozoic or Transition.

Permian

Carbonic (Pennsylvanic)

Mississippic

Devonic

Siluric

Ordovicic

Cambric

### Eozoic (Proterozoic) or Primary in Part.

Algonkic or Huronic

### Azoic (Archaeozoic) or Primary.

Archaic



**GEOLOGICAL HORIZON.** A given level in the geological column—recognizable by fossils or otherwise at different localities. A certain moment in the geological history of the earth.

**ERA, PERIOD, EPOCH, AGE.** Successive divisions of geologic time.

**DIVISION, SYSTEM, SERIES, STAGE.** Corresponding divisions of the geological column.

**FORMATION.** The geological unit—characterized by similarity of lithological features and organic remains. Formations are named from the locality where best developed and first studied then becomes the type locality.

**GROUP.** A division of the geological column of variable value comprising two or more formations, according as used—Hamilton group, Monroe group, etc.

**STRATUM.** A single lithological unit. A layer or bed—bedded formations are stratified.

**SUPERPOSITION OF STRATA OR FORMATIONS.** The original order of succession in which the strata or formations were deposited.

**CORRELATION.** The identification of strata or formations of equal age, i.e., formed at the same time, over wide areas, by various means, such as superposition, lithologic and stratigraphic continuity, organic contents, etc.

**II. PALAEOONTOLOGY.** The Study of Fossils. "Fossils are the remains of animals or plants, or the direct record of their presence, preserved in the rocks of the earth's crust from the earliest to the present time."

**INDEX FOSSILS.** Characteristic fossils by which a given geological horizon may be recognized at different localities.

**LABORATORY WORK WITH RECENT AND FOSSIL PLANTS.**

Trays A. 1-10.

**I. PROTOPHYTA.** The simplest unicellular plants of low organization. They include the Bacteria, which are known from the Palaeozoic on, often placed under the Algae.

**II. THALLOPHYTA.** Comprise plants of low order consisting of a "thallus" which shows no differentiation into stem, leaf or root. They include—

1. Algae,
2. Fungi,
3. Lichens.

1. **ALGAE**, or sea weeds are divisible into three groups, according to their coloring matter, viz: (a) Green algae, (b) Brown algae, and (c) Red algae.

(The Bacteria, etc., are often included as a separate group—the Blue-green algae.)

(a) **Green Algae**—Represented by modern sea lettuce (*Ulva*) a thin bright green leaf-like thallus, common on seashore. Many forms secrete lime as *Halimeda* which is common on coral reefs—and *Chara* (1 a) the common stone-wort found in fresh water pools and lakes; it makes fresh water marl and limestone. The spore fruit is globular or ovoid with spiral ridges and is often found fossil. (1b)

(b) **Brown Algae**—Often of large size, as the common Devil's Apron, or *Laminaria* (1c) which

grows 3 or 4 metres in length with a stout stalk ending in a branching rootlike manner, grasping stones or shells. The blade, stalk and "root" commonly covered with great variety of organisms. Giant kelp of the Pacific (*Macrocystis*) said sometimes to reach a length of three hundred meters. The common rock weed, *Fucus vesiculosus* (1d) covers rocks between tide. Furnished with air bladders; usually has many animals (bryozoa, hydroids, etc.) attached. The Gulf weed *Sargassum* is closely related. Found south from Cape Cod, floats in *Sargassum* sea. Many animals live on it.

The Diatoms (1e) are microscopic brown algae secreting a siliceous skeleton which is preserved. Habitat planktonic in open sea or benthonic on other seaweeds; also in fresh water. Capable of motion. Skeleton a highly ornate transparent "frustule"—of two parts "box and lid" like; forms diatomaceous earth (1)✓ often of great thickness as under Richmond, Va. ✓

(c) Red Algae—of many shades, mostly marine. *Chondrus crispus* or Irish moss is collected as food. Many microscopic. Several secrete lime, i.e., the Coralline seaweed or Nullipore. Corallina, a branching brittle form, Lithothamnion (2)✓ forms pink encrustations on stones, smooth or knobby. Becomes white when dry. Important on coral reefs. me

Fucoids (3) a name applied to impressions on rock believed to be of fossil seaweeds. Clau

2. FUNGI, low terrestrial plants, destitute of chlorophyl or leaf-green, depend for food on organic matter either living (parasitic) or dead (saprophytic). They include the rusts, mildews, smuts, etc., and the toadstools, mushrooms and shelf fungi (*Polyporous*, *Daedalia*, etc.) (4) commonly growing on trees.

3. LICHENS—Terrestrial plants formed of fungi growing in intimate (symbiotic) association with various forms of algae. Cover stones, tree trunks, fences etc., as a grayish curly crust, often with reddish-brown cup-like spore fruits (Par-melia) (5), or hang in tufts from branches of trees in swamps, etc., like the long gray Usnea (5a).

III. BRYOPHYTA. Mosses. These are for the most part land plants, growing in woods and swamps, with stems and leaves and fruit spores. They include the Liverworts like the scale moss (Madotheca), the true mosses (musci) which include the Peat mosses, Hypnum and Sphagnum. (6), the hairy cap moss (Polytrichum) (6a), the pine tree moss (Clemacium) (6b) and many others. Mosses are rare as fossils.

IV. PTERIDOPHYTA or Fern plants. The highest of the flowerless plants or Cryptogams. They include (1) the horse tails or Equisetales, (2) the Club mosses or Lycopodales, (3) the extinct Sphenophyllales, and (4) the Ferns or Filicales.

1. Equisetales or horse tails—represented by the living genus, Equisetum (6c) growing in low moist ground, and along railroad embankments. It has a creeping root stock of a meter or more in length, and two kinds of branches—a coarse one, bearing a spore cone, and a slender sterile one with many branches, both are jointed and hollow. Plant rough and gritty, due to presence of flint particles. Fossil representatives of this group are the Calamites (6d) which grew to the size of trees in Carbonic time from 30 to 60 meters high. They had a thicker wall, and were generally preserved as stony casts.

2. Lycopods, or Club mosses include the ground pine Lycopodium (6e) of our woods, bearing leaves and numerous spores (Lycopodium powder) and the extinct tree-like Sigillaria (6f) with their trunks marked by leaf scars in vertical rows and Lepidodendron (6g) with the scars in spirals. The creeping root of these is called Stigmara (6h) and bore many rootlets.

3. Sphenophyllum (6i) consists of long slender stems with whorls of leaves. Entirely extinct.

7. Ferns—include (a) the common forms (6j) which are represented by numerous genera and species, mostly low—some forming low trees (in tropics). The frond consists of a stipe or leaf stalk arising from an underground stem or rhizome and the blade, often divided into many pinnules. Fruit in form of spores, often on under-side of frond. (b) The Water ferns or Rhizocarps (6k) which live in water, often floating, spores of such types (Protosalvinia) (6l) occur in quantities in black shales of Ohio, etc., and are believed to be source of petroleum. (c) Palaeozoic forms and cycad ferns (7) many of them of a higher order than living ferns and related to the Spermaphytes.

V. SPERMAPHYTA or seed plants. These include Gymnosperms or naked seeded plants, and the Angiosperms, or covered seed plants.

A. The Gymnosperms include conifers, cycads, joint firs, and the extinct Cordaites (8) with strap-shaped leaves. Cycads are palm-like plants common in the Mesozoic. Conifers begin in the late Palaeozoic and are represented to-day by the yews (Taxus), the Japanese ginkgo, the pines, spruce, fir, hemlock, tamarack, cypress, arbor vitae, etc.

B. The Angiosperms include the remaining flowering plants and are divided into:

1. Monocotyledons, or endogenous plants including the lilies, palms, the grasses (including the cereals) banana, ginger, etc., orchids, the water plantain and arrow head and others—pondweed (including the eel grass, *Zostera* (8d), the cat tail, etc. They have mostly parallel veined leaves and flowers in parts of threes. Their growth is from within. They first appear in the early Mesozoic.

2. Dicotyledons, or exogenous plants, which include the largest number of plants such as the butter cup, rose, pink, etc., with separate petals, (Choripetalae or Polypetalae), the honeysuckle, huckleberry, lilac, etc., with petals more or less united (Gamopetalae) and the Buckwheat, sorrel, pepper, mistletoe, nettle, etc., without petals (Apetalae). Under these groups are also included the common deciduous trees (oak, maple, tulip, willow, etc.). Dicotyledons first appeared in the Cretacic. (8f).

## LABORATORY WORK WITH RECENT AND FOSSIL ANIMALS.

Trays A. 1-10-continued.

### I. PROTOZOA.

1. Foraminifera: *Globigerina* (9a), one of the common forms leading pelagic (planktonic) life in open ocean. Shells accumulate as *Globigerina* ooze on ocean bottom. Note successively added chambers and foramina or pores. *Orbiculina* (9) a shallow water form, abounds in sand of coral islands in tropics. Note successive addition of linear chambers, also spreading of form.



Nummulites (10) A fossil foraminiferon abounding in Eocenic seas. Note numerous chambers enclosing one another.

Chalk (11) is largely composed of microscopic foraminifera besides other calcareous organisms. In the slide (11a) note Textularia one of the common types, with cells arranged biserially, and Rotalia with cells arranged in spiral (Cretacic age).

2. Radiolaria—Protozoa of pelagic (planktonic) habitat. The highly ornate siliceous or glass shells are internal and accumulate in deeper part of sea forming radiolarian ooze. Barbadoes earth (12a), fossil radiolarian ooze from Barbadoes; radiolarite (12b) a flinty or cherty rock composed largely of the shells of radiolaria.

## II PORIFERA:

Sponges—Main mass of dried specimens (13) consists of net-work of horny fibres—the supporting structure from which flesh has been removed. It encloses one or more cylindrical spaces, each opening above in an osculum. Water passing through body mass, ejected again from osculum. In many sponges siliceous spicules (13a) more or less replace the horny fibres. In many fossil sponges (13b) fibres are all siliceous. Some sponges tunnel into shells or rocks to which they grow (Boring sponge, Clione sulphurea—14).

## III COELENTERATA:

1. Hydrozoa (Hydroids) mostly marine, generally colonial, attached to rocks or sea weeds. Body covered by delicate horny sheath either furnished with numerous bell-shaped hydrothecae or cups, each on a stem and enclosing a polyp, (Campanularia, 15a) or with a double row of close set hydrothecae (Sertularia, 15b). When dried the sheath

alone remains, a horny substance, suggestive of delicate seaweeds (15).

*Dictyonema* (17)—a fossil form (*Graptolite*) represents the sheath compressed on shale into carbonaceous film—the several strands connected by cross-threads into a net work. The cups seldom visible.

2. *Hydrocoralline*: A group in which the sheath is replaced by a calcareous structure resembling coral. *Millepora* (16). The cups open by pores on the surface of the structure—there being two sets of different sizes—the larger (*gastropores*) lodging the feeding polyps, the smaller (*dactylopores*) the fighting polyps. In section note that the tubes (the representative of the cups) are successively divided off by floors or *tabulae*. Common on coral reefs. Fossil representatives of this group are known as *Stromatopora* (18) in which the calcareous material is deposited in successive layers. An important reef builder of Palaeozoic time. Sometimes formed masses 10 ft. in diameter.

3. *Actinozoa* (*Corals*). The skeletal structure (*corallum*) of calcium carbonate or lime alone remains—see illustrations in *Saville-Kent, Great Barrier Reef*, for aspect and color of polyps.

*Eusmylia* (19) a simple recent coral. Note radiating plates or *septa* and wall—increase by division of older individuals.

*Streptelasma* (20) a simple fossil coral showing wall and *septa*—interspaces filled with mud hardened into rock.

*Madrepora* (21) (*Stag-horn coral*). A recent compound branching coral with small individuals separated by solid calcareous tissue. *Septa* rudimentary. A common reef builder of to-day.



*Astræa* (22) (Star coral) compound "head," consisting of closely arranged individuals, each showing septa wall, etc. A modern reef builder.

*Acervularia* (23) fossil *Astræan* coral showing septa and wall in each individual. Interspaces all filled by lime mud, hardened to rock, hence polishing was possible. A Palæozoic reef builder—often of great size.

Trays A. 11-20.

#### IV MOLLUSCOIDEA

##### 1. BRYOZOA:

Minute colonial organisms chiefly marine, encrusting sea weed stalks, etc. *Membranipora* (1) consists of numerous small calcareous cells, each one lodging an animal (zooid). *Monticulipora* (2) a fossil Bryozoan of the Palæozoic. The cells are deep, closely crowded and divided off into tiers by tabulae.

##### 2. BRACHIOPODA:

Shell of two valves, dorsal and ventral—the valves nearly equal as in *Lingula* (3a) and attached by long fleshy stem or pedicle; or more generally unequal in size as in *Terebratula* (3). Each valve is symmetrical with reference to median line. Larger valve with round foramen through which fleshy pedicle projects as shown in recent *Terebratula* (3b).

*Strophomena* (4) one valve concave leaving very narrow space for soft parts of animal. Hinge elongated, with flattened hinge area. Symmetry as in *Terebratula*.

#### V MOLLUSCA

##### 1. PELECYPODA: (Bivalve Mollusks).

Shell of two valves—right and left. Generally equal in size and form as in *Venus* (5) or *Cardita*

(6) or slightly unequal but with the valves nearly symmetrical as in the scallops or Pecten (7). Increase of shell by addition of layers around initial point or beak. Surface smooth but marked by growth lines (5) or with radiating plications (6 and 7). Form nearly circular as in Cardita (6) or elongate as in Mytilus (8). Interior of valve showing muscle scars, etc. (5). Fossil forms often very similar to recent ones as in Modiola (9).

## 2. GASTROPODA (Snails).

Spirally coiled shells either low spired as in the garden snail *Helix* (10) or the sea snail *Nerita* (11) or elongate spired as in *Turritella* recent (13) or fossil (14). Aperture round with reflexed lip as in *Helix* (10) with sharp lip (11) with spinous lip as in *Murex* (11a) or with lip notched at back and often drawn out into a canal as in *Fusus* or *Purpura* (12). The shell is sometimes cup-shaped, as in the Limpet, and this has sometimes an apical hole as in the keyhole Limpet *Fissurella* (15).

## 3. PTEROPODA (Sea Butterflies).

Shells small, generally more or less transparent, of variable form. The simplest a small, slender, tapering tube (*Styliola*) (16a) living near the surface of the ocean as plankton, the dead shells accumulating as Pteropod ooze on the ocean floor. *Styliolina* (16) a fossil form compressed on shale makes up limestone in the Devonian, estimated to contain 40,000 individuals to the cubic inch. (17).

## 4. CEPHALOPODA.

To this class belong the living cuttle fish, Squid, Devil fish, *Nautilus*, and a host of fossil forms. *Nautilus* (18a) builds a shell coiled in a single

plane and divided by septa which are pierced by the siphuncle. *Orthoceras* (18) is like *Nautilus* straightened out. When the shell is removed, as is usually the case, the edges of the septa are seen and the space between filled with hardened mud. Note position of siphuncle (not always clearly shown). Specimens showing shell partly preserved are rare (18b).

*Ammonites* (19) are fossil forms with shells often ornamented and with the edges of the septa highly fluted and complexly folded. They are all extinct. *Ceratites* and *Goniatites* are early forms.

*Spirula* (19a) is a modern coiled shell entirely within the animal. It shows the septa and siphuncle.

*Belemnites*. A fossil form with the shell or phragmocone (20a) enclosed in a calcareous guard (20) which is commonly cigar-shaped and has a conical depression for the reception of the shell at one end.

## VI VERMES—WORMS.

Marine, fresh-water and terrestrial animals mostly without hard parts capable of preservation. One order builds tubes either of cemented sand grains or of lime. *Serpula* (21) is an irregular tube attached to shells or occurring in clusters. *Spirula* is a spirally coiled tube found in deeper water, both recent (22) and fossil (23) attached to seaweed, shells or other objects of support. Worm tubes in sand of sea shore are U-shaped, two sides separately preserved, as in *Scolithus* (23a). Worm castings often preserved in rocks resulting from hardening of old mud flats (23b). Internal jaws (*Conodonts*) also preserved (23c).

## VII ARTHROPODA

### A. Crustacea.

1. Malacostraca: The highest order represented by Decapoda, (ten-footed crustacea) which comprise lobsters and crayfish (*Macrura*) (24a) with elongate cephalothoracic shield and long ringed abdomen; 5 pair of walking legs of which one is generally modified into a grasping claw (chela); with antennae, stalked eyes, mouth parts, etc., and Crabs (*Brachyura*) (24b) with broad, more or less flattened carapace, five pair of walking legs, one clawed, abdomen tail-like, commonly turned under. Fossil Decapods are often found represented by claws only in Mesozoic and Cenozoic strata (24), also whole carapaces.

2. Cirripedia: include the barnacles, degenerate crustacea attached to rock, etc., acorn barnacle (*Balanus*) (25) or by fleshy stem to logs, etc.; goose barnacle (*Lepas*) (26). Both types found fossil.

3. Ostracoda are minute bivalve crustacea often making up masses of rock, either marine (*Leperditia*, etc.) (26a) or fresh water (*Cypris*, etc.) (26b).

4. The order Trilobita is the most important extinct order, entirely confined to the Palaeozoic (27) composed of head, thorax and pygidium—each showing central axis and sides. Eyes often well developed, compound legs and antennae rarely preserved. Head often with separate "free cheeks." Thorax jointed, often permitting enrollment.

### B. Acerata

5. Merostomes are highly developed Arthropods. Crustacea like. Body sometimes encased in

solid carapace with only telson movable as in the modern horse-shoe crab or *Limulus* (27a) or with the thorax and abdomen both ringed and not separable as in *Eurypterus* (27b), a Palaeozoic form.

**VIII ECHINODERMATA.** ("Spiny Skinned") Marine organisms—one group represented by the star fish, a common recent form (28) and also found fossil (28a). The Brittle star (28b) also found fossil. A second group comprise sea urchins having a calcareous "test" made of spine-bearing plates; abundant in modern seas (*Strongylocentrotus drobachiensis*) (29) and fossil chiefly in the Mesozoic and later. The form is regular with central mouth as in *Cidaris* (30) and with large spines (31); or irregular; of elongate form with mouth at one end, as in *Maretia* (32). The third class comprises the crinoids which are represented by recent forms in tropical seas (33a) and by fossil forms (35). They consist of a calyx (35) bearing arms (33) and generally attached by a stem or stalk (34). Two other types belong here, both extinct, the Blastoid (*Pentremites*) (36) with regular bud-like form, and the Cystoid (37) composed of irregular plates. Both were attached by stems and had rudimentary or no arms.

#### **IX VERTERBRATA.**

These have internal skeletons generally capable of preservation, and often external limy or calcareous armors. Dermal spines, teeth, etc., are also capable of preservation. Include: Fish, Amphibians, Reptiles, Birds and Mammals.

#### **STRATIGRAPHIC MAPS AND SECTIONS.**

##### **THE PRE CAMBRIC.**

Foundation complex of crystalline rarely unmetamorphosed rocks, generally divisible into

Archaean and Algonkian or Huronian. Underlies all later formations.

Distribution: North America. Canadian shield and Newfoundland, Wisconsin—Michigan area, Adirondack area and Southern Appalachians: original centers of deposition. New England—Hudson area; Rocky Mountains area and small patches in Texas, Missouri and the Cordilleran area mostly brought up by subsequent folding or faulting.

Europe. Northwest Scotland and Highland area in part and Ireland—Fenno-Scandia, Central France. Main centers of deposition of early Palaeozoic strata. Patches in Alps, Bohemia, etc., brought up by subsequent disturbance and erosion.

Origin: Archaean granites, gneisses, schists, etc. metamorphic mainly from ancient volcanic and other igneous rocks—some ancient sediments. Algonkian or Huronian—largely sediments, but mostly formed by rivers on land; fossils are seldom well preserved. Much metamorphism.

Contents: Much of metallic mineral deposit of world in the Pre Cambric. Not all metamorphic nor all mineral bearing deposits are Pre Cambric—some very recent.

### THE CAMBRIC.

(Laboratory Trays B. 1—10.)

Named by Sedgwick from Cambria—ancient name of North Wales.

Two-fold division over earths' surface—Atlantic type, Pacific type. In each a threefold division recognizable, lower, middle and upper.

Greatest development in America.

Lower. In Atlantic province called Etcheminian from Indian tribe. Zone fossil *Holmia*.



Pacific—called Georgian from Georgia Vermont. Zone fossil *Olenellus*.

Middle. In Atlantic called Acadian from Eastern Canada. Zone fossil *Paradoxides*. Pacific (not named). Zone fossil *Olenoides*.

Upper. Atlantic or Bretonian (from Cape Breton Island) Zone fossils: *Olenus* (14) *Microdiscus*, (13) Pacific or Saratogan (from Saratoga, N. Y.) (Potsdamian) Zone fossils *Dikelocephalus* (14b) *Lingulepis* (14c).

Transition zone to Ordovician. (Tremadoc division) contains *Dictyonema* (15).

Distribution and character: Atlantic province: Eastern New Foundland, New Brunswick and Cape Breton, etc.,—Eastern Massachusetts, England, Baltic region, Mediterranean region and Bohemia, the most famous section. Barrande placed all older fossiliferous rocks of Bohemia in the Silurian System and divided it into rocks with primordial or first fauna,—second and third fauna. The first fauna is the Cambrian (middle). Pacific province: Cordilleran region to Rocky Mountains, Texas, and extending northeast where now are Appalachians—through Pennsylvania, New Jersey, Eastern New York and Western Massachusetts, Vermont, Quebec to Western Newfoundland to Arctic Sea which covered north Scotland, China, Siberia, etc., also in India and Australia. Changes and rearrangements of shore lines in these periods are pronounced.

Material. In Pacific province basal sands passing up into limestones; shales rarer. In Atlantic muds and some limestones—the latter thickest in Mediterranean region.

## CHARACTERISTIC COLUMNAR SECTIONS

1 **PACIFIC REGION:** Nevada: Mostly limestones L. 4500 ft. M. 2600 ft. U. 1000 ft. Montana: L. absent, M. shales and limestones 1200 ft. U. absent by erosion. Colorado: (Rocky Mt. front range, L. & M. absent U. Sandstone 100 ft. or more. Progressive overlap from west to east.

2. **CENTRAL NORTH AMERICA:** Southern Appalachians: Mostly limestones, L. 7000 ft. or more, M. 2000 ft. U. 3500 ft. Missouri: limestones, L. absent M. 200. ft. U. 100 ft. partial reduction of thickness by erosion. Minnesota. L. & M. absent, U. sandstone, 500 ft. partial reduction of thickness by erosion. Potsdam: special name for upper Cambric.

## LABORATORY WORK WITH FOSSILS.

(Trays B. 1-10.)

### PRESERVATION.

#### A. Actual record of entombment.

I. Original substance preserved. Soft parts as insect in amber (1a). Mammoth in ice. Original hard parts—shark's tooth (1), bones, shells.

II. Substance altered (a) by carbonization, as in *Dictyonema* (15), (b) by replacement with silica as in silicified shells (2) or silicified wood (3).

III. Original substance destroyed. Impression or mold alone remains. Illustrated by artificial mold of pelecypod (*Arca*), both internal and external (4) and natural mold of pelecypod (5) artificial internal mold of *Helix* (6); natural internal mold of *Turritella* (7).



B. Impressions left in transit. Foot prints (7a), trails (7b) of organisms, as in *Arthropycus* (7c).

C. Artificial structures. Structures built by organisms from foreign substances, e.g., worm tubes as in *Scolithus* (10).

D. Coprolites or excrements of characteristic form, e.g., those of Jurassic Reptiles (7d).

### DISTORTION OF FOSSILS.

By pressure, during folding or other tectonic movements fossils are often distorted so as to lose their original form. Flattening from settling of sediments is a common mode of distortion. (8).

### PSEUDOFOSSILS.

Delicate films of oxide of iron or manganese often simulate ferns or other fossil impressions; these are the dendrites (9).

### CAMBRIC FOSSILS.

(Trays B. 1-10-continued.)

*Dictyonema* (15). Note fan-like branching and cross-threads, cups or thecae generally not shown. (See diagram). Cambro—Ordovician transition zone.

*Scolithus* (10). Note smooth pencil-like filling of old tubes. Walls of tubes are agglutinated. Potsdamian.

*Olenellus* (12a). Besides form, note long pygidial spine; absence of suture, which would cut off free cheeks; outline of central part of head or glabella. Georgian.

Paradoxides (12). Note broadening glabella; separation of free checks. (Acadian).

Microdiscus (13). Minute head and pygidial shields. No eyes. (Bretonian).

Olenus (14). Rather square glabella. (Bretonian).

Dikellocephalus (14a). Large size; form; note spines on pygidium. (Potsdamian).

## THE ORDOVICIC SYSTEM (Laboratory Trays B. 11-20.)

Named by Lapworth from ancient inhabitants of Western England. Originally called by Murchison Lower Silurian and by Sedgwick Upper Cambrian. Two main types of sedimentation known: the sandstone-limestone type around the Canadian shield and in the Baltic and Mediterranean areas, and the sandy shale and shale type with graptolites, found more especially in marginal regions of the continents. A third type consists of river and wind laid sediments, formed in eastern United States and some other regions, and which are partly of a red color suggesting arid conditions.

Standard Series:

Fossils:

Upper or Trentonian.

Richmond formation . . Rhynchotrema (14)

Lorraine . . . . . Platystrophia (13)

Eden—(Frankfort) . .

Utica . . . . . Diplograptus (10)

Triarthrus (11)

Trenton, Prasopora (5) Dalmanella (15)

Plectambonites (16). Orthoceras

(6) Asaphus (7). Trinucleus

(8).

Middle or Chazyan.

Black River . . . . .	Columnaria	( 4 )
Lowville . . . . .	Phytopsis	( 3 )
Chazy . . . . .	Maclurea	( 2 )

Lower or Beekmantownian.

Beekmantown forma- tion . . . . .	Ophileta	( 1 )
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CHARACTERISTIC NATURAL SECTIONS.

1. Lake Champlain section. Strata dip gently east; rest on crystallines of Adirondacks. Potsdam s. s. 1150 ft. followed by Beekmantown, 1800 ft.; Chazy, partly concealed under lake but forming islands—900 ft.; Black River 80 ft.; Trenton 300 ft.; Utica 600 ft.; cut off by thrust fault on east bringing up Cambrian.

2. Mohawk Valley section. Strata dip gently south. Adirondack crystallines; followed directly by lower Beekmantown 350 ft. forming cliffs; hiatus; Lowville (Upper Chazy) 30 ft.; Black River 10 ft.; Trenton limestone (at Trenton Falls) 250 ft.; Utica shale at Utica on Mohawk 600 ft.; Frankfort shale 100 ft.; hiatus; Oneida conglomerate forming cliffs 40 ft.; (Silurian).

3. Western New York section. Dipping gently south. Crystallines of Canada. Black River limestone 20 ft. Trenton limestone 900 ft. Utica—Lorraine 600 ft. mostly under Lake Ontario—Oswego sandstone 75 ft. (deepest part of lake). Queenston red shale and sandstone (Richmond) 1100 ft. (only 100 ft. above south shore of Lake Ontario). Medina sandstone (Silurian).

4. Upper Mississippi Valley section. Dip gently southeast. Crystallines; St. Croix (Potsdam) sandstone with *Dikellocephalus* 600 ft. Magnessian limestone (Beekmantown) 200 ft. St. Peter sandstone 150 ft. Stones River (Upper Chazy) 40 ft. Black River 50 ft. Galena limestone with *Receptaculites* 200 ft. forming cliffs; hiatus; Maquoketa (Upper Richmond) 50 ft.; Niagara (Siluric).

5. Rocky Mountains section. Dipping about 30 degrees east. Granite; Basal sandstone (Potsdam) 30 ft.—Beekmantown limestone 200 ft.; hiatus; Lower Trenton limestones 300 ft.; hiatus; Upper Richmond limestone 100 ft.; hiatus; Mississippic limestones.

6. Appalachian sections. Beds dipping at angles of 45 degrees to 90 degrees—sandstones commonly form sharp ridges. Shales and limestones form valleys.

6a. Central Pennsylvania. An anticline; beds on western limb vertical, on eastern dipping 45 degrees E. In center Upper Kittatinny limestone (Upper Cambrian); Beekmantown limestone 2500 ft.; Chazy limestone 2500 ft.; Black River 100 ft.; Trenton limestone 600 ft.; Utica shale 650 ft.; Frankfort and Lorraine 350 ft.; Bald Eagle Conglomerate (Lorraine or Early Richmond) forming Bald Eagle Mountain on west and Nittany Mountain on east 350 ft. Juniata, red sandstone (Richmond) 500 ft. Tuscarora sandstone—Medina—Siluric (forming ridge) 500 ft.—Nittany Mountain is a syncline, with highest beds in center Juniata red beds.

6b. Eastern Tennessee. Beds form monocline dipping about 45 degrees to the S. E. crest of Clinch Mountain is formed by sandstone of that name. Knox dolomite (Upper Cambrian) 3500 ft. —forms broad valley. Chickamauga limestone—1700 ft. (Chazy); Sevier shale 600 ft. (Trenton); Bays Red sandstone 325 ft. (Richmond); Clinch sandstone 200 ft. (Medina), Rockwood formation 650 ft. (Niagara); hiatus; Hancock limestone 275 ft. (Helderberg); hiatus Black shale—Devonic to Mississippic—valley formation.

## LABORATORY WORK WITH ORDOVICIC FOSSILS

(Trays B. 11-20.)

1. *Ophileta*—Beekmantown. Note numerous whorls, coiled nearly in a plane; gradual enlargement of coil, flat under and keeled upper side.

2. *Maclurea*—Chazy. Flat spire showing all coils—left-handed coiling, rapid enlargement, triangular section of whorl.

3. *Phytopsis*—Lowville. A series of tube-like or rod-like structures embedded in fine lime mud—as grass stems might be buried in mud accumulating around them. Section shown in all directions.

4. *Columnaria*—Black River. Compound, of slender prismatic tubes striated exteriorly, divided by crossplates or tabulae interiorly.

5. *Prasopora*—Trenton. Note form; wrinkled epitheca of flat base, finely prismatic tubes seen in section.

6. *Orthoceras*—Trenton. Slender subcylindrical form gradually tapering, divided by concave septa. On surface of septum, note connecting tube or siphuncle.

7. *Asaphus*—Trenton. Similarity of head and pygidium, the former distinguished by large eyes; body (thorax) of a number of rings.

8. *Trinucleus*—Trenton. Head with three rounded lobes, the middle one largest. Outer rim ornate, with rows of pits. Lateral spines long—seldom preserved.

9. *Receptaculites*—Galena. Form watch-glass-shaped; like the bottom of a beaker-like or jar-like structure; walls composed of rods with crossbars at both ends, of saw-horse type. Arrangement such as to give external pattern resembling markings on machine-turned watch case.

10. *Diplograptus*—Utica. Slender, shiny black mark on surface of shale. Note toothed margins, formed by compressed cups or thecae.

11. *Triarthrus*—Utica. Head with square glabella, marked by backward converging furrows. Body (thorax) of many rings.

12. *Rafinesquina*—Cincinnati group. Concavo-convex, two valves almost in conjunction with little space between. Straight hinge-line, narrow hinge area, surface with alternating radiating striae.

13. *Platystrophia*—Cincinnati group. Coarsely plicate, long straight hinge line and areas on both valves. Median depression (sinus) on one, elevation (fold) on other valve, both plicate.

14. Rhynchotrema—Cincinnati group. Like preceding but without straight hinge line and area.

15. Dalmanella—Cincinnati group. Hinge line short, area comparatively small, form nearly round. One valve convex the other flat or with median depression.

16. Plectambonites—Cincinnati group. Like No. 12 but smaller and proportionally wider and more convex.

17. Monticulipora—Cincinnati group. Of fine prismatic tubes, like No. 5, but different in form; surface aperture of tubes polygonal.

18. Calymmene—Cincinnati group. Head with strongly divided median part (glabella), eyes and outline also distinctive.

## THE SILURIC SYSTEM.

Named by Murchison from old English tribe of Silures. Restricted in America chiefly to central United States and northward. Mainly limestones and calcareous shales, with marine fossils in lower and upper part, and shales, red sandstones, conglomerates, salt and gypsum beds in the middle.

### Standard Series.

Subdivision . . . . . Fossils.

Upper or Monroan.

- II w Manlius limestone . . . . . Tentaculites.
- Rondout water-lime . . . . .
- I 176 Cobleskill limestone . . . . . Halysites. *cham. area*
- II 405 Bertie water-lime . . . . . Eurypterus.
- Lower Monroe beds . . . . .



Middle or Salinan.

Salina shales, gypsum and salt.

Lower or Niagaran.

I 92 Guelph dolomite.....

II 404 Lockport Limestone..... Halysites.

I 224 Rochester shale..... Caryocrinus.

I 247 Clinton Limestone and shale Pentamerus.

Medina sandstone..... Arthropycus.

CHARACTERISTIC SECTIONS.

1. Niagara Section: From Lake Ontario to Buffalo. Continuation of Ordovician section, No. 3. Beds nearly horizontal. Most of series exposed in Niagara escarpment (200 ft. high) at Lewiston. Queenston red shales (Ordovician) mostly under Lake Ontario,—about 60 ft. shown. Medina sandstone 125 ft.; Clinton group 40 ft.; Rochester shale 75 ft. (forms Cave of Winds with Clinton limestone as floor). Lockport and Guelph dolomite 200 ft. (the Falls over lower 80 ft.; rapids 50 ft. higher). Salina shales and gypsum 350 ft. Bertie water-lime 60 ft. Cobleskill 7 ft.; hiatus; disconformity; Onondaga (Devonic).

2. Rosendale Section: Beds inclined 30 degrees west. Rest unconformably upon folded Hudson River shale. Shawangunk conglomerate 200 ft. Longwood shale, etc., 40 ft. Rosendale water-lime 20 ft. Cobleskill limestone 15 ft. Rondout water-lime 20 ft. Manlius limestone 50 ft. Coeymans (Devonic).

3. Appalachian Sections: Clinch Mountain. Dip 45° to S.E. upper part of Ordovician section No. 6b. Western part of mountain formed by outcrops of Ordovician strata to Bays sandstone.



Clinch sandstone 200 ft. (Medina) forms crest of mountain. Rockwood sandstones, shales and iron ores 650 ft. (Niagaran). Hiatus cutting out Middle and Upper Siluric; Hancock limestone (Devonic) or Black shale follows.

4. Central New York Section: Continuation of Ordovician section No. 2. Dip gently south. Resting disconformably on Frankfort shale (Ordovician). Oneida conglomerate 40 ft. (cliff former), Clinton-Niagara shale and sandstones 250 ft. Salina shales and gypsum 1000 ft. Bertie water lime 50 ft.; Cobleskill 10 ft.; Rondout water lime 20 ft.; Manlius limestone 50 ft.; Coeymans 5 ft. (Lower Devonian).

#### LABORATORY WORK WITH SILURIC FOSSILS. (Trays C. 1-10.)

1. *Lingula*, Medina. Note pointed form; shell symmetrical; horny character.

1a. *Arthropycus*, Medina. Crossing of ridges. Note peculiar ornamentation of same. Occurs as molds on underside of rock corresponding to impression in mud beneath.

2. *Anaplotheca*, Clinton. Limestone mass compares as coaly streak on shale. Note arrangement

3. *Pentamerus*, Clinton. Large smooth symmetrical shells. Valves nearly equal, often only one shown.

4. *Monograptus*, Clinton. Compressed, appears as coaly streak on shale. Note arrangement and form of serrations (compressed hydrothecae).

5. Clinton iron ore. Note color, softness, etc.

6. *Fucoid*, Clinton. Impression on shale or sandstone. Note branching and general outline.

7. Rochester shale, typical calcareous shale with *Bryozoa*.

8. *Caryocrinus*, Rochester. Nut-like form. Note point where stem was attached; also bases of arms. Trace outlines of plates of calyx, and ornamentation on same.

9. *Calymmene*, Niagaran limestones and dolomites. Often fragmentary. Head with median lobe or glabella strongly and peculiarly notched, this being character by which genus is recognized. Note form of cheeks, eyes, character of body lobes and form of pygidium, if present.

10. *Halysites*, Chain coral, Lockport, also Cobleskill. Compressed tubes oval in section unite by narrow sides, form irregular links.

11. *Orthoceras annulare*. Lockport, etc. Compare with Ordovician *Orthoceras*. Note elevated rings with fine wrinkled lines between. Edges of concave septa do not correspond to rings.

12. Shawangunk Conglomerate. Quartz pebbles rounded. Note general absence of other minerals than quartz. In character often like Bald Eagle or Tuscarora-Clinch, or Oneida.

13. Longwood shale. Typical red shale, in all essentials like Juniata, Bays or Queenston shale. Indications; semiarid climate during formation.

13a. *Eurypterus*, Bertie. Note head with eyes; body of numerous rings; tail-spine; appendages or paddle legs and walking legs.

14. Tentaculites, Manlius, or Tentaculite limestone. Slender, tapering tubes strongly ringed.

15. Leperditia, Manlius. Bean-like, two valves with straight hinge-line, eye tubercle.

## THE DEVONIC SYSTEM.

(Laboratory trays C. 11-20; D. 1-10 in part).

Name from Devonshire in Southwestern England, where marine formations of this age were first studied by Murchison and Sedgwick. Equivalent to Old Red System of Scotland.

Types of Sedimentation. (1) The open marine type consists of sandy beds and shales with pelecypods in Eastern North America, becoming calcareous shales with brachiopods further west, and coral reef limestone in Central and Western United States.

(2) Black shale type (Ohio type), probably in large part a delta deposit, like that of the Mississippi. Contains much fossil wood, but few animals. Also large spherical concretions.

(3) Continental type,—both gray and red. Characteristic of eastern United States and Canada. Oneonta and Catskill red sandstones, Gaspé sandstones, with plants, fresh water mussels and peculiar fish. Old Red sandstone of Scotland of this type—sometimes red sandstone or coarse conglomerate or fine grained flag stone (Caithness).

Distribution. Lower Devonian beds are found chiefly in eastern and southern United States, and in Rhine Valley region of Europe. Middle Devonian widespread in North America, often coral reefs. An eastern and a western type. Upper Devonian,

American or Ithaca type, foreign or Naples type, the latter most widely distributed.

Standard Series.

Subdivisions                      Fossils

Upper Devonic.

Chemung (or Catskill)—*Spirifer disjunctus*, (fish, plants.)

Portage beds.

Naples phase—*Goniatites*, *Spirifer glabra*.

Ithaca phase—*Brachiopods*.

Oneonta phase—*Plants*, *Unios*.

Genesee shales—*Plants*, *Styliolina*.

Tully limestone—*Rhynchonella*, (*Hypothyris*) *cuboides*.

Middle Devonic:

Hamilton group—*Spirifer mucronatus*, corals, etc.

Marcellus black shales—*Pelecypods*, *Styliolina*.

Onodaga limestone—*Corals* (*Favosites Zaphrentis* etc.).

Schoharie and Esopus grits.

Lower Devonic:

Oriskany sandstone—*Spirifer arenosus*  
*Rensselaeria*.

Helderbergian beds—

Port Ewen—*Leptaena*.

Becraft—*Gypidula pseudogaleata*.

New Scotland—*Spirifer macropleura*.

Coeymans—*Gypidula galeata*.

## CHARACTERISTIC SECTIONS.

1. Helderberg Section. (Continuation of Siluric section, No. 2.) Beds gradually becoming horizontal, at first inclined  $30^{\circ}$  west. Coeymans limestone 50 ft.; New Scotland shaly beds 75 ft.; Becraft limestone 30 ft.; Port Ewen shaly beds 150 ft.; Oriskany sandstone, etc. 60 ft.; Esopus-Schoharie shales 350 ft.; Onondaga 75 ft. (forms cliffs); Marcellus-Hamilton shales 600 ft.; Upper Hamilton sandstones 500 ft. (Lower flag-stones); Oneonta sandstones (Upper flag-stones) 3000 ft.; Catskill red sandstone and conglomerate 1700 ft.

2. Central New York Section. Continuation of Siluric section No. 4, from south of Utica in zigzag line to Elmira, passing through Clinton (site of Hamilton College); Oriskany battlefield; Hamilton (site of Colgate University); Tully; Ithaca (Cornell University) to Chemung River, near Elmira (State Reformatory).

Resting conformably on Manlius: Coeymans 5 ft.; erosion surface, hiatus; Oriskany sandstone 20 ft.; hiatus. Onondaga limestone 100 ft.; Marcellus shale 180 ft.; Hamilton shales 1200 ft.; Tully limestone 50 ft.; Genesee shale 100 ft.; Lower Portage sandstone (Naples fauna) 250 ft.; Ithaca shales 450 ft.; Upper Portage (Naples) shales and sandstones 600 ft.; Chemung sandstones and shales 1200 ft.; Catskill shales 1250 ft.; Olean (Carbonic) conglomerate at State line.

3. Western New York Section. Continuation of Siluric section 1 from Buffalo along Lake Erie to Dunkirk, then south to Pennsylvania line at Olean and Bradford. Beds nearly horizontal. At Buffalo resting disconformably on Cobleskill (eroded): Oriskany-streak; Onondaga limestone

200 ft.; Marcellus shales 200 ft.; Hamilton shales 200 ft.; Tully and Genesee very thin, Portage shales and sandstones 1300 ft.; Chemung shales and sandstones 1500 ft.; Cattaraugus shales and conglomerates.(transition beds)300 ft.hiatus;Oswayo shales (Pocono) 250 ft. hiatus; Shenango shales (Mauch Chunk) 80 ft.; hiatus; Olean conglomerate (Carbonic).

4. Ideal Section of Middle Devonic. Hamilton formation from the Hudson to Lake Michigan. Beds originally horizontal. Sandstone and conglomerates of terrestrial origin with plant remains in east. Merge westward into marine sandstones with mollusks, in western New York become calcareous shales with brachiopods and thin limestone beds and gradually limestone becomes more prominent until on Lake Michigan all is limestone.

5. Ideal Section of Upper Devonic, (Portage formation,) in New York, showing faunas. On the east Continental Oneonta, plants and Unios, then shales with Ithaca fauna then shales and sandstones with Naples fauna west of Central New York. In Central New York inter-fingering of two types. Followed by invasion of Chemung fauna from west and Catskill Continental sedimentation from east, the latter gradually overlapping the former.

#### LABORATORY WORK WITH DEVONIC FOSSILS. (Trays C. 11-20; D. 1-10 in part).

1. *Gypidula galeata*, Coeymans. Shell with symmetrical valves, larger one strongly over-arching,



plicate; smaller one (often not visible or absent), much flatter.

2. *Spirifer macropleura*, New Scotland. Large with few coarse plications. Also fine striations when shell is preserved.

3. *Gypidula pseudogaleata*. Becraft. Like (1) but smooth.

4. *Leptaena rhomboidalis*. Helderbergian, etc. Straight hinge-line, concentric wrinkles, abrupt bending down in front.

5. *Spirifer arenosus*, Oriskany. Large with regular plications which cover median depression (sinus) and elevation (fold).

6. *Rensselaeria*, Oriskany. Symmetrical valves nearly equal, elongate, with numerous regular striations.

7. *Favosites*, Onondaga—prismatic columns, showing mural pores.

8. *Favosites*. Same as No. 7, with tubes broken lengthwise showing horizontal plates or tabulae.

9. *Favosites*, Hamilton. Small, entire heads showing surface opening of tubes.

10. *Acervularia*, Western Hamilton. Compound with prismatic tubes, center of each strongly depressed; well marked septa.

11. *Diplophyllum*, Western Hamilton. Cylindrical tubes well developed; septa and tabulae well marked.

12. *Pleurodictyum*, Hamilton, Small heads of large and small tubes.

13. *Zaphrentis*, Onondaga. Conical with somewhat bi-laterally arranged septa and deep septal groove or fossula.

14. *Streptelasma*, Hamilton, With radially arranged septa—otherwise much like preceding.

15. *Heliophyllum*, Hamilton, Large, coarsely wrinkled, numerous septa with cross-bars or carinae.

16. *Cystiphyllum*, Hamilton, Like preceding but without septa. A cystose structure in their place.

17. *Spirifer mucronatus*, Hamilton. Transversely elongated, plicated on either side of fold and sinus; narrow hinge area.

18. *Stropheodonta*, Hamilton. Concavo—convex shell, surface striated; hinge line with fine vertical teeth.

19. *Atrypa*, Hamilton. Robust, one valve, much deeper. Surface striate; no area.

20. *Athyris*; Hamilton. Smooth, nearly circular, valves nearly equal, very convex.

(Trays D. 1-10 in part).

1. *Spirifer laevis*. Portage; large, smooth with shallow median depression.

2. *Goniatites*, Portage. Generally strongly compressed. Coiled in plane, with angular septal margins.

3. *Spirifer disjunctus*, Chemung. Elongate, with many plications, extending over fold and sinus; internal mold deeply cleft or disjointed.



4. Black shale. Representative of Marcellus, Genesee and Portage, black shales.

5. Red sandstone. Representative of Catskill and Old Red of Europe.

## MISSISSIPPIC, CARBONIC AND PERMIC SYSTEMS.

(Trays D. 1-10 in part).

These comprise the old Carboniferous system, so named from the presence of coal for which it is the lowest horizon. Chief coal deposits found in the Carbonic (also called Pennsylvanic). Mississippic, named from Mississippi Valley where it is well developed, Permian named from district of Perm in Russia.

### Standard Series.

Permian (German divisions).

Zechstein.

Rothliegende.

(Eastern American).

Dunkard or Upper Barren.

Carbonic: (Eastern North America).

Monongahela—or upper productive.

Conemaugh—or lower barren.

Alleghany—or lower productive.

Kanawha.

Pottsville (Millstone grit).

Mississippic: (Miss. Valley).

Chester,

St. Louis,

## Waverlyan.

Warsaw,  
Keokuk,  
Burlington,  
Kinderhook.

In the Permian of North Europe great salt deposits (Stassfurt region); in Southern hemisphere evidence of glaciation abounds (S. Africa, India, Australia, South America).

Dwyka conglomerate of South Africa, typical example of ancient boulder clay (tillite).

In North America as well as Europe the Mississippic deposits are mostly marine except in Appalachian region, where they are continental. Carbonic deposits of Continental origin in part, contain coal beds, the lowest productive beds being in the Pottsville, e.g. Pocahontas coal, Quinnimont coal, etc. Other important coals in Kanawha of W. Virginia. The Alleghany contains the Clarion, Kittanning and Freeport coals. The Monongahela, the Pittsburg coal at the base and the Waynesburg at the top. Conemaugh and Dunkard contain only thin, mostly unimportant coals.

### Characteristic Sections.

1. Appalachian section. Schuylkill River. A series of folds. Section begins in Blue Ridge with Shawangunk conglomerate resting unconformably against Hudson River shales. Shawangunk conglomerate 30 ft.; Longwood red shale 1700 ft.; Lewiston limestone (Monroe) 30 ft. (top of Siluric); hiatus; Oriskany sandstone 30 ft.; hiatus Hamilton and Portage 2000 ft. Catskill red sandstone 5000 ft.; Pocono sandstone and conglomerate 1500 ft.; Mauch Chunk red shale 2000 ft.; Pottsville conglomerate 1250 ft.; Kanawha formation 1300 ft.; Alleghany 300 + ft.

Anticlines have vertical western limb, eastern limb about 45 degrees. First syncline halfway between Blue Ridge and Pottsville; Catskill in center; followed by anticline exposing top of Longwood; syncline at Pottsville carrying Kanawha and Alleghany; broad anticline exposing Portage in center; Small syncline with Catskill; east branch of Susquehanna. Beyond river axis of anticline exposing Longwood; syncline with Catskill, anticline in Portage, then beds follow to Pottsville in gradually dying out folds.

Shawangunk, Portage, Pocono and Pottsville form mountains.

2. Ohio-Western Pennsylvania Section. Beds nearly horizontal. Rest on Ohio Black shale. (Devonic), Waverly group, consisting of Bedford shale 85 feet; Berea grit 40 ft; Sunbury shale 15 ft.; Cuyahoga formation 300 ft.; Black Hand 40 ft. Logan sandstone 115 ft. (Kinderhook to Koekuk=Pocono); hiatus; Maxville limestone (Chester) 25 ft.; hiatus; Sharon conglomerate 100 ft. (Upper Pottsville); Mercer group (with Connoquenessing sandstone at base and Homewood at top age Kanawha) 200 ft.; Alleghany formation 350 ft.; Cone-maugh 600 ft.; Monongahela 375 ft.; Dunkard or Washington 1200 ft.

3. Mississippi Valley Section: Beds nearly horizontal, resting unconformably on Devonic: Kinderhook shales and limestones 140 ft. Burlington 100 ft.; Warsaw 40 ft.; hiatus; St. Louis 200 ft.; Chester 200 ft.; hiatus (cutting out Lower Carbonic Arkansan), followed by shales and limestones of Middle Carbonic or Des Moines, which comprises in Kansas: Cherokee 450 ft. and Mar-

maton 385 ft.; then Upper Carbonic or Missourian comprising Pottawatomie 735 ft.; Douglas 190 ft.; Shawnee 507 ft. Succeeding this are Permian shales and limestones comprising Wabaunsee 300 ft.; Cottonwood 125 ft.; Chase 255 ft.; Sumner 350 ft.; and the red Cimarron sandstones shales and gypsum 1400 ft.. Disconformity; Cretacic beds.

## LABORATORY WORK WITH MISSISSIPPIC, CARBONIC AND PERMIC FOSSILS.

(Trays D. 1-10 in part).

6. *Dizygocrinus*. Burlington; sub-spherical form of regularly arranged series of smooth plates in lower part with scar of stem attachment, and irregular plates in upper part (tegmen) prolonged into central anal tube. Arm openings around middle.

7. *Macrocrinus*, Burlington. Calyx pear-shaped, top (tegem) sloping, arm bases about 14, anal tube (often broken away) long.

7a. *Lithostroton*, St. Louis. Compound; tubes prismatic, septa well developed meet in center in pronounced columella.

7b. *Melonites*, St. Louis. Melon-shaped. Ambulacral and interambulacral areas each of numerous rows of small plates, the former with pores.

8. *Pentremites*. Chester. Bud-like form; note five petaloid ambulacral areas and five openings on top—the largest opening includes anus. Mouth in centre.

9. Crinoid stem. Ordovician to recent; Mississippian. Composed of discs or joints more or less flexible. Surface of disks radially striate. Median canal. Form and ornamentation varies greatly.

10. *Fusulina*. Carbonic limestone (marine). Elongate spindle-like form. In section note spiral coiling and successive chambers.

11. *Productus*. Carbonic limestone (marine), symmetrical when not compressed. Large valve strongly curved with incurved beak. Hinge line straight often spiny—surface with interrupted ridges and spine.

12a. *Pecopteris*, Carbonic concretion. Mid-rib with numerous closely set pinnules, joining it with straight base at nearly right angles.

12b. *Neuropteris*, Carbonic concretion; single large pinnule with indented base. Note forked veining.

12c. *Calamites*, Carbonic, stony cast—rarely with bark preserved. Note jointing and vertical striations.

12d. *Sigillaria*. Carbonic. Often with bark preserved but flattened. Vertical ridges with leaf scars between.

12e. *Lepidodendron*, Carbonic. Same as preceding, but leaf scars in diamond-shaped areas.

12f. *Stigmaria*. Carbonic. Root stock of preceding found in under-clay or sand, rootlets attached at circular scars..

12g. *Cordaites*, Carbonic. Strap-shaped leaf with parallel veining.

13. Mauch Chunk Red Shale. Mississippic. Similar to older red shales.

14. Pottsville conglomerate. (Millstone Grit), with rounded quartz pebbles like Shawangunk, etc. Pocono often more sandy.

15. Coal shale (Roof shale). Carbonic. Showing plant impressions.

16. Carbonic sandstone, prevailing rock of Coal Measures.

### GENERAL PALAEOZOIC SECTIONS.

1. Central Wisconsin, S.E. to Central Michigan. Strata dip gently S.E. On Precambrian of Wisconsin: St. Croix (Potsdam) sandstone 600 ft.; Lower Magnesian limestone (Beekmantown) 200 ft.; St. Peter sandstone 150 ft.; Stones River, Black River, and Galena, 300 ft.; hiatus; Maquoketa 50 ft.; Niagarian limestone with iron ore at base 800 ft.; hiatus; Monroe dolomites (Upper Silurian) 500 ft.; hiatus; Salina with salt and gypsum 1000 ft.; hiatus; Onondaga 150 ft.; Traverse group (Hamilton) 600 ft.; Antrim Black shale 200 ft.; hiatus; Waverly group 1000 ft. Coal Measures 700 ft.

Green Bay excavated in Maquoketa shale, cliff on southeast, of Niagarian limestone which dips under Lake Michigan. Islands in lake, partly Monroe, partly Onondaga. East shore of Lake Michigan, formed by Traverse limestone cliffs.

2. Rocky Mountain Section. Strata dip 30 degrees east. On granite of Pike's Peak is basal Deadwood sandstone ("Potsdam", or Upper Cambrian), 30 ft. Followed by Manitou limestone (Beekmantown) 200 ft.; hiatus; Lower Fremont limestone (Trenton) 300 ft.; hiatus; Upper Fremont limestone (Maquoketa) 100 ft.; hiatus; Mill-sap limestone (Mississippian) 400 ft.; Fountain red



sandstones and shale (Carbonic) 2000 ft.; fault bringing Upper Fountain beds vertically against the others; Chugwater red beds (Triassic).

## MESOZOIC SECTIONS. TRIASSIC SYSTEM.

Original sub-division in Germany threefold.

3. Upper Trias or Keuper.
2. Middle Trias or Muschelkalk.
1. Lower Trias or Bunter sandstone.

1 and 3 continental deposits; 2 is marine. In Alps and India extensive limestone series represent whole Trias. In England only red sandstones, called New Red (in part Permian). Red sandstones with basalt flows and intrusions (Newark system) of Keuper age, in eastern North America from Nova Scotia to Pennsylvania; coal beds in place of basalt from Pennsylvania to Carolina. In Western U. S. east of Cordilleras, red and variegated sandstones form principal deposits, sometimes with extensive petrified forests, as in Arizona. On Pacific Coast (California, Nevada, Oregon, Idaho, Utah), marine limestone with *Ceratites* occur.

## JURASSIC SYSTEM.

Named from occurrence in Jura Mountains, mainly limestones, some shales and sandstones. Upper division in southern Germany contains lithographic limestones.

Typical European Succession.

3. Upper or White Jura or Malm.
2. Middle or Brown Jura or Dogger.
1. Lower or Black Jura or Lias.



In America marine limestones and shales only in Pacific States, with arm reaching to Black Hills. Represents only part of series. Along Front Range beds are of continental origin, with remains of huge reptiles (Dinosaurs, etc.) Eastern United States, mainly clays and sands.

### COMANCHIC SYSTEM.

Named after Comanche tribe of Indians in Southern U. S. where system is best developed. Mostly limestones, some shales and sandstones.

#### Typical Succession.

4. Dakota sandstone—transition member.
3. Upper Comanchic or Washita.
2. Middle Comanchic or Fredericksburg.
1. Lower Comanchic or Trinity.

Most typically developed in Mexico, Texas, Oklahoma, North to Kansas. On Atlantic Coast mainly clays and sands. In Europe limestones, clays, etc. Greensands and clays in England.

### CRETACIC SYSTEM.

Named from occurrence of chalk (creta) in England and France. Chalk composed largely of foraminiferal shells. Flint concretions in layers. In Central United States mostly shales and limestones; on Atlantic Coast, clays, sands and greensands. On Pacific Coast mostly shales.

#### Characteristic American Succession.

Upper Cretacic or Laramian.

Middle Cretacic or Montanan.

Fox Hill series.

Pierre series.

Lower Cretacic or Coloradoan.

Niobrara series.

Benton series.

Dakota Sandstone, transition series.

### CHARACTERISTIC SECTIONS.

1. From the Black Forest southwest through the Swabian Alb to the foot of the Alps. Strata dip gently southwest, becoming steeper in Upper Swabia, where they form broad syncline and are turned up nearly vertically at the Alps where much faulting and thrusting occurred.

Begins at Rhine Graben, a fault valley bounded by step faults and occupied by Oligocenic, Pliocenic and Quaternary deposits. Black Forest of gneisses and intrusives, followed by Bunter sandstone, overlapping Rothliegende sandstone of Permian. Succeeded by Muschelkalk, and Keuper. Neckar Valley and Tubing on Muschelkalk; hills beyond of Keuper capped by Rhaetic and Lias limestones and Marls. Dogger-beds seen in face of Swabian Alb which is formed by great limestone beds of White Jura. This sinks to valley of Danube from which stream to the Alps is a broad syncline of Tertiary and Quaternary strata. In Alps, Tertiary is much faulted with steep dips and overthrusts by Cretacic limestones and then by Triassic and some Jurassic limestones, all strongly folded.

2. Across Central England, from Pre-Cambrian area of Long Mynd in Shropshire to London. On crystallines rest Cambrian dipping steeply east followed unconformably by Upper Ordovician at a lower angle. Then with another slight unconformity and still gentler dip follow Silurian shales and limestones, the latter forming escarpment (Wen-

lock edge). Followed by Ludlow or Upper Siluric and a part of Old Red sandstone into which it grades. Then with a disconformity follow Carbonic Coal Measures and some Permian red sandstone, all dipping gently east. Then follows New Red Sandstone forming Worcester lowland; crossing the Severn, we find Lias clays, still in low country. Crossing the Avon below Stratford, we ascend the Cotswold hills, a much dissected escarpment of Lower Oolites. Then we descend to valley at Oxford, formed of Middle and part of Upper Oolites (Dogger and part of Malm) which are here mostly clays. Hiatus, cutting out part of Upper Jura and Lower Comanchic. Green sand and Gault clay lie at foot of Chiltern Hills escarpment, capped by white chalk. Descending back of chalk slope we come to Eocenic clays and sands of London area—dipping under the sea.

3 Rocky Mountains (Bighorn Mts.) Beds dipping  $45^{\circ}$  east, later becoming horizontal. Rest on granite. Deadwood sandstone 1000 ft. (Cambrian); Bighorn limestone, (Ordovician) 100 ft.; hiatus; Madison limestone 500 ft. (Mississippian) forms ridges. Carbonic and Permian limestone and sandstone 350 ft.; Chugwater red beds (Triassic) 1200 ft.; Sundance (Marine Jurassic) 450 ft. Morrison (Continental Jurassic) 250 ft.; Dakota s.s. 100 ft. Benton shales 1300 ft. Niobrara limestone 200 ft. Pierre shales 2000 ft. Fox Hills beds 300 ft.; Laramie beds with coal 3000 ft.; Tertiary (non marine) 5000 ft.

4. New Jersey to Connecticut Valley, showing Newark system. Rest on old peneplain surface of schists and gneisses. West of Hudson, beds dip 15 or 20 degrees west. All red sandstones, with in-

cluded sill of Palisade diabase near bottom and two sheets of basalt in upper part. Becomes very coarse towards border of crystallines. Fault at Hudson; brings shist to level of Cretacic penneplain. In Connecticut Valley beds dip east. Several faults traverse it. Lava sheets form ridges. Small area of down-faulted Newark 30 miles west of Connecticut Valley.

5. Atlantic Coastal Plain. Strata dipping gently east. Resting unconformably on Pre-Cambrian and on folded Triassic. Potomac formation comprising: Patuxent clays 100 ft. Arundel clays 125 ft. (Jurassic); Patapsco 240 ft. (Comanchic); Raritan sand 400 ft. (Dakota, top of Comanchic); Hiatus. Ripleyan 500 ft. (Middle Cretacic). Jerseyan 175 ft. (Upper Cretacic); Shark River beds (Eocenic).

## LABORATORY WORK WITH TRIASSIC AND JURASSIC ROCKS AND FOSSILS.

(Trays D. 11-20).

### TRIASSIC.

1. Triassic Sandstone. Typical of Newark, of Triassic of Western America, of New Red Sandstone of England and of Bunter sandstone of Germany.

2. Fossil fish. Flattened on black shale, representing temporary water bodies.

2a. Footprint of Dinosaur. Impressions and mold of same from Newark sandstone.

3. *Estheria*. Fossil Branchiopod crustacean—two-valved. Fresh water.

4. Fossil Wood. Petrified forest of Arizona, entirely replaced by silica.

4a. *Ceratites*. Muschelkalk, Germany. Note coiling in single plane; heavy ribs; sutures of many forward bending saddles and backward bending lobes, the latter serrated.

4b. *Encrinus liliiformis*, Muschelkalk, Germany. Note regular arrangement of plates of calyx and arms; stem of alternating joints.

5. Trap Rock. Characteristic of Newark system. Nova Scotia to New Jersey.

## JURASSIC.

6. *Belemnites*. Note cigar-shaped guard; radial structure where broken; deep conical hollow for insertion of actual shell or phragmocone (6a) (Western America).

7. *Gryphaea incurva* Lias. Very convex under valve, with incurved beak; upper valve small, operculum-like. Europe.

8. *Ammonites (Amaltheus) margaritanus*, Lias. Coiling in single plane, laterally compressed, whorls somewhat embracing; ornamented by ribs. Keel with rope-like ornamentation. Suture complex. Europe.

9. *Pentacrinus* stem, Lias. Joints pentagonal, highly ornate.

9a. *Ichthyosaurus*, Lias. Fish lizard. Extinct marine reptile. Europe.

10. *Ammonites* (*Stephanoceras*) *humphriesianus*, Dogger. Note rounded whorls partly embracing—strong ornamentation on inner half of whorls. Europe.

11. Lithographic Stone. Malm, with floating crinoid, and dendritic markings. Solnhofen.

12. Fossil Fish. Malm. Lithographic limestone. Solnhofen.

12a. *Limulus*, or Horseshoe Crab, Malm; Lithographic limestone. Solnhofen.

12b. Fossil Dragon Fly. Malm. Lithographic limestone. Solnhofen.

#### LABORATORY WORK WITH COMANCHIC AND CRETACIC ROCKS AND FOSSILS.

(Trays E. 1-10).

1. *Gryphaea corrugata* (Comanchic). Elongate deep lower valve, with incurved beak, broad hinge area, single muscle scar; upper valves flat.

2. Leaf of Dicotyledonous plant. Cretacic, Dakota sandstone, form often outlined in precipitated iron oxide.

3. *Exogyra costata* Cretacic: Montanan. Lower deep valve as in *Gryphaea*, but beak twisted exteriorly on one side. Surface ribbed.

4. *Inoceramus deformia*. Niobrara. Large, coarse, shell thick, of prismatic columns. Surface with strong concentric wrinkles.

5. *Inoceramus crispii*. Cretacic: Montanan. Smaller than No. 4, elongate, shell thinner: concentric wrinkles marked.



6. *Gryphaea convexa*. Ripleyan of Atlantic Coast. Compare with No. 1. beak smaller, less incurved.

7. *Ostraea*. Laramie. Differs from *Gryphaea* in shallower valve, beak not incurved.

8. *Ostrea falcata*. Ripleyan. Small plicated, sickle-shaped valves.

9. *Exogyra arietina*. Small; lower valve strongly coiled, resembling some gastropods.

10. *Bacculites*, Montanan. Straight, compressed, septa with much folded margins.

11. *Scaphites*, Montanan. Coiled in single plane, last portion somewhat loosely coiled; shell with ribbed and in older specimens, noded exterior.

12. *Terebratella*. Shell with symmetrical, strongly plicated valves, straight but narrow hinge area.

13. Greensand. (Glauconite). Cretacic. Mostly formed as internal molds of foraminiferal shells. Wide spread in Cretacic.

14. Chalk. Composed largely of foraminiferal shells (see slide) characteristic of Upper Cretacic of Western Europe.

15. Flint Nodules. Occur in layers in chalk. Often accumulate around a sponge or other organism as nucleus.

16. Laramie plant. Characteristic of coal swamps of Laramie time.



## CENOZOIC (TERTIARY). SYSTEMS.

The early division, made in 1828, by Lyell, was into Eocene (dawn of recent, with 3½ per cent. of recent species of shells). Miocene (medial recent 17 per cent. recent species), and Pliocene (late recent, with 35 to 50% of recent species). These percentages are no longer relied upon. Oligocene coined subsequently by Beyrich for part of Upper Eocene and Lower Miocene of North Germany.

Two types of sedimentation—the marine and the non-marine. In North America marine confined to Atlantic and Gulf coasts. In Europe, more widely spread, but generally in basins, Eocenic best developed in London, Hampshire and Paris Basins. Oligocenic in North Germany widespread but mostly under cover—in the Rhine Valley especially at Mainz and Cassel, etc. Miocenic especially in Vienna Basin, and in Western France, and Pliocenic especially in Italy. In America marine Oligocenic and Pliocenic are best developed on Gulf Coast.

### Characteristic Sections.

1. Atlantic Coastal Plain. Dipping gently eastward, resting discomformably on Ripleyan Cretacic. Pamunkey sands and clays (marine Eocenic) 200 ft.; hiatus; Oligocenic wanting. Chesapeake sands and clays (marine Miocenic) 400 ft.; Lafayette (Pliocenic, non-marine) 50 ft.; Columbia gravels (Pleistocenic) 30 ft.

2. Gulf Coast. Dipping gently southward resting discomformably on Ripleyan Cretacic. Eocenic: Claytonian limestone, etc. 200 ft.; Chickasawan sands and lignites, 900 ft.; Buhrstone beds, 300 ft.; Claiborne formation 140 ft.; Jacksonian limestone, 150 ft. Oligocenic: Vicksburg limestone 200 ft. Chattahoochee beds, 70 ft.; Chipola marls

50 ft. Miocenic: Chesapeakeian, etc. 80 ft.; Pliocenic Caloosahatchie beds 50 ft. Pleistocenic, gravels and Loess 100 ft.

3.. Great Basin and Plains Sections. These are horizontal strata of terrestrial origin—mostly fluvial or eolian, and not always represented in the same locality. The succession from below up is: Eocenic 4600 ft. divided into: Puerco 500 ft.; Torreon 300 ft. Wasatch 200 ft. Wind River 800 ft. Bridger 2000 ft. Uinta 800 ft. Oligocenic 1300 ft. Comprising only the White River 800 ft., and the Lower John Day about 500 ft. Miocenic, 1000 ft. + comprising the Upper John Day 500 ft. the Deep River 150 ft.; the Loup Fork 400 ft. Pliocenic, comprising only the Blanco formation 150 ft. and Pleistocenic represented by the Sheridan beds 100 ft. thick.

#### LABORATORY WORK WITH CENOZOIC (TERTIARY) AND PSYCHOZOIC (QUATERNARY) FOSSILS.

1. *Turritella mortoni*; Eocenic. Internal mold—note spiral coil.

1a. *Turritella mortoni*, shell; Eocenic, whorls with spiral ornamentation.

2. *Terebratula*, Eocenic. Unequal but bilaterally symmetrical valves, large formamen of pedicle valve, surface smooth.

3. Nummulites, Eocenic. Note form; compare section in Trays A 1-10, Europe.

4. *Cerithium*. Eocenic, compare with *Turritella*. Note greater ornamentation and notch in lip.

5. *Lamna*—Sharks tooth. Eocenic.
6. *Lamna*—vertebra—Eocenic; bi-concave.
7. *Turritella*, Miocenic, compare with 1 and la.
8. *Crepidula*, Miocenic. Spire small on one side. Broad shelf-like columella.
9. *Arca*, Miocenic. Note teeth and hinge area
10. *Arca*, Miocenic. Compare with 9.
11. *Chama*, Miocenic. Roughly coiled, lower valve, upper valve flat, two muscle scars, surface rough.
12. *Glycimeris* (*Pectunculus*), Miocenic. Nearly round symmetrical valves, note hinge teeth and area, compare with 9; Surface with plications.
13. *Lucina*, Miocenic, compare with 12.
14. *Crassatellites*, Miocenic. Elongate strong hinge teeth, peculiar form.
15. *Pecten*, Miocenic. Note form and size. Nearly symmetrical, strong ornamented plications.
16. *Maretia*, Oligocenic; form; disposition of ambulacral areas, mouth, anus, etc.
17. *Cladophyllia*, Pliocenic. Long cylindrical, septa in multiples of six.
18. *Saxicava*, Pleistocenic, elongate shell, rough exterior.

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