REFERENCES

CONTENT

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THE GEOLOGIC COLUMN

	ERA	SYSTEM OR PERIOD	SERIES OR EPOCH	STANDARD TIME SCALE*
Phanerozoic	Cenozoic	Quaternary	Holocene (Recent)	0.01
			Pleistocene	2.5
		Neogene	Pliocene	7
			Miocene	26
		Tertiary		
		Paleogene	Oligocene	38
			Eocene	54
			Paleocene	65
	Mesozoic	Cretaceous	Upper, Lower	136
		Jurassic	Upper, Middle, Lower	190
		Triassic	Upper, Middle, Lower	225
	Paleozoic	Permian		280
		Carboniferous		
		Pennsylvanian	Upper, Middle, Lower	325
		Mississippian	Upper, Lower	345
		Devonian	Upper, Middle, Lower	395
		Silurian	Upper, Middle, Lower	430
		Ordovician	Upper, Middle, Lower	500
		Cambrian	Upper, Middle, Lower	550
	Precambrian		Upper, Middle, Lower	4600

*Represents millions of years; not endorsed by the author.

NOMENCLATURE CHART OF FORMATIONS

Cenozoic	Eocene	Wasatch (Claron) Formation
		San Jose Formation
	Paleocene	Nacimiento Formation
Mesozoic	Cretaceous	Ojo Alamo Sandstone
		Cliff House Sandstone
		Menefee Formation
		Point Lookout Sandstone
		Castlegate Sandstone
		Blackhawk Formation
		Starpoint Sandstone
		Mancos shale
		Dakota Formation
		Cedar Mountain Formation
		XXXXXX Major hiatus
	Jurassic	Morrison Formation
		Summerville Formation
		Curtis Formation
		Entrada Sandstone
		Carmel Formation
	Triassic	Navajo Sandstone
		Kayenta Formation
		Wingate Sandstone
		Chinle Formation
		Shinarump Conglomerate
		XXXXXX Major hiatus
		Moenkopi Formation
		XXXXXX Major hiatus
Paleozoic	Permian	Kaibab Limestone
		Toroweap Formation
		Coconino Sandstone
		XXXXXX Major hiatus
	Pennsylvanian	Supai Group
	Mississippian	Redwall Limestone
	Devonian	Temple Butte Limestone
	Cambrian	XXXXXX Major hiatus
		Muav Limestone
		Bright Angel Shale
		Tapeats Sandstone
Precambrian	Proterozoic	Sediments, schists and granites

INTRODUCTION TO INTRODUCTORY PETROLOGY

"THE FIVE MINUTE ROCK COURSE"

Petrology is the study of rocks. **Rocks** are aggregates of minerals of varying size, composition, physical characteristics and origin. This latter factor is especially important in present classification schemes.

The **minerals** which form rocks are composed of atoms that are organized into highly defined substances with more or less constant physical and chemical properties. Examples of minerals include diamond, rock salt, graphite, quartz, etc.

A rock, on the other hand, is not so well defined; it can consist of a single or many minerals mixed in various proportions, sizes, etc. The important features of a rock can tell us much about its past history, and this is particularly important as one considers the past history of Earth.

There are three major groups of rocks — igneous, sedimentary, and metamorphic. Their major features will be described below.

IGNEOUS ROCKS

These rocks are formed by the congealing of hot molten material called magma. The hardening of a molten volcanic flow would be an example. Hardening can take place either below or above Earth's surface. Some identifying characteristics of igneous rocks are:

Usually not in layers, at least, not fine layers
Hard and massive
Interlocking mineral crystals

EXAMPLES

Basalt — fine crystals, dark in color from the more rapid cooling of magma.

Granite — consisting of coarse, light and dark interlocking crystals, not in layers, often from slow cooling of magma, but can also be of metamorphic origin.

Ophiolite — group of medium to dark igneous rocks including basalt, derived in part by metamorphism and associated with the development of a geosyncline.

Volcanic breccia — hardened coarse, angular particulate products of volcanoes.

SEDIMENTARY ROCKS

These rocks are formed by the cementing together of fragments aggregated together by various transport mechanisms such as moving water, wind, flowing ice, etc. An example would be the cementing together by minerals of sand particles on a beach to form beachrock or sandstone. Some identifying characteristics of sedimentary rocks include:

Layering
Particulates often rounded by transport
Sorted according to size by transport

EXAMPLES

Anhydrite — hard whitish rock composed of anhydrous calcium sulfate.

Claystone — massive, indurated clay particles.

Conglomerate — cemented round to subround pebbles in a finer matrix.

Dolomite — carbonaceous sedimentary rock, often greyish-tan in color, with a dominance of the mineral dolomite which is a calcium-magnesium carbonate.

Evaporite — composed primarily of minerals such as rock salt, gypsum, anhydrite, thought to have originated by the evaporation of saline solutions.

Gypsum— soft whitish rock composed of hydrous calcium sulfate.

Limestone — usually massive calcium carbonate, often white to grayish, produced by precipitation of lime from seawater either inorganically or by living organisms.

Marl — usually composed of fine impure calcium carbonate with some clay. An ill-defined term.

Sandstone — cemented sand.

Sedimentary breccia — composed of coarse angular clasts and originating from a sedimentary process.

Shale — cementing of fine particles, finely laminar.

METAMORPHIC ROCKS

These rocks originate from igneous, sedimentary, or other metamorphic rocks. They are altered physically or chemically or both, producing a new kind of rock. These changes occur essentially in the solid state and can be either minor or of such a nature as to completely change the characteristics of the original rock. An example would be the changing of a shale into a slate by shearing pressure. Characteristics of metamorphic rocks are:

Generally laminated
Original structures out of shape, hard to identify
Contains mineral assemblages characteristic of metamorphic changes

EXAMPLES

Gneiss — foliated rocks with alternating mineral bands, usually formed from coarser grained rocks, layer greater than 1 mm in thickness.

Granite — coarsely crystalline rock, consisting of light and dark (usually) minerals, sometimes derived by the metamorphism of sedimentary rocks, also of igneous origin.

Marble — from limestone, usually not in layers, altered and bent carbonate crystals.

Mylonite — compact, fine-grained rock produced by extreme mechanical granulation and shearing during metamorphism.

Phyllite — compact, fine grained, usually intermediate between a slate and a schist. Does not cleave as perfectly as a slate.

Schist — strongly foliated crystalline rock, easily split, originating from fine-grained rocks, layers 1 mm or less in thickness.

Serpentine — rock with a black to green, greasy luster, soapy feel, derived from metamorphism, magnesium-rich rocks.

Slate — compact, fine grained, very fine layers, can be split into slabs and plates, usually from shale.

STRATIGRAPHIC SECTION: COLORADO PLATEAU

This is a selected list from the most important formations. Depositional environments given are those implied in the standard literature.

CENOZOIC

QUATERNARY

Various alluvial (recent stream, flood, and lake deposits) and eolian (wind-blown) deposits.

TERTIARY

Sevier River Formation (probably Pliocene)

Grey, partly consolidated, coarse conglomerate with volcanic debris. Thickness to 250 m. Fluvial (river) deposit.

Brianhead Formation (Eocene to Miocene? Probably Eocene)

Grey, consolidated ash flow. Thickness to 300 m, usually thinner. Fossils? Volcanic origin.

Wasatch Formation (also called Claron in S)

Pink, white limestone and calcareous sandstone, soft, conglomeratic at base. Invertebrate and plant (angiosperms) fossils. Thickness up to 1100 m; usually 150 m. Considered to be a freshwater deposit; fluvial (river), paludal (swamp), and lacustrine (lake) environments described.

San Jose Formation (Eocene)

Buff, grey, etc., mudrock with interbedded sandstones. Cuba member is prominent at base. Thickness up to 630 m. Was called Wasatch in north before formation worked out. Has yielded one of the most diverse Eocene vertebrate fauna. Deposited by rivers (fluvial), includes flood plain and sheet sandstone deposit. Paleocurrent data indicates high-energy streams from the north.

Naciamento Formation (Paleocene)

Grey to variegated (multicolored) black and white mudstones and sandstones. Thickness up to 525 m. The formation is famous for its Paleocene vertebrate fossils, especially early mammals. E.D. Cope reported about these. Fluvial (river) and lacustrine (lake) paleoenvironment

MESOZOIC

CRETACEOUS

Ojo Alamo Sandstone (Cretaceous from vertebrate evidence, but Tertiary from few plant fragments). Thickness up to 35 m. Vertebrate and plant fossils. Continental (land) paleoenvironment.

Kirtland Shale and Fruitland Formation

Grey to variegated (multicolored) sandstones, shale and coal. Upper Kirtland with more shale. Both with thicknesses up to 500 m. Many vertebrates, fish to mammals, including dinosaurs,

crocodiles, turtles, invertebrates and plants. Important coal source. Fluvial (river) deltaic, paludal (swamp), coastal paleoenvironment.

Pictured Cliffs Sandstone (Upper Cretaceous)

"Salt and pepper" sandstone. Thickness up to 60 m. Deposited in a regressive marine offlap of a littoral (intertidal) marine environment. Named for the thousands of "fantastic figures" engraved on the massive sandstone exposed along the San Juan River.

Lewis Shale (Upper Cretaceous)

Dark-grey to drab-grey sandy shale with clay and sandstone and calcareous concretions, and thin white-to-grey sandstone layers. Thickness up to 600 m. Marine fossils include bivalves and ammonites. Marine paleoenvironment. Extends from New Mexico to Montana

MESAVERDE GROUP

Forms a variety of outcrops in different localities. In general it consists of buff, bedded sandstone layers with interbedded shale members, many of which are carbonaceous. Coal seams common, dinosaur tracks, upright trees; marine fossil layers also common. Intertongues with Mancos Shale. Thickness up to 1500 m.

In the Mesaverde region, the group includes the following three formations:

Cliff House Sandstone (Upper Cretaceous)

Thin-bedded to massive buff sandstone with shale partings. Thickness up to 250 m. Deposited in a transgressive (inundating sea) marine paleoenvironment.

Menefee Formation (Upper Cretaceous)

Interbedded grey-buff sandstones, grey shales, and coal seams. Thickness up to 700 m. Fossils include fish, turtles, crocodiles and many plants. Nonmarine, fluvial (river) and coastal paleoenvironment, possibly some marine deposits.

Point Lookout Sandstone (Upper Cretaceous)

Massive, light-grey to yellow sandstone. Thickness up to 100 m. Littoral regressive (receding sea), marine paleoenvironment, sediments supplied by rivers, in part fluvial (river) - deltaic, strand (shore) plane, and barrier beach deposit.

In eastern-central Utah the group includes the following four formations:

Price River Formation (shale; piedmont environment)

Castlegate Sandstone (floodplain environment)

Blackhawk Formation (coal and sandstone; lagoonal environment)

Star Point Sandstone (littoral — intertidal — marine environment)

Mancos Shale

Evenly bedded, light- to medium-dark grey, calcareous, marine shale which weathers yellowish grey. Limestone and sandstone members present. Intertongues with Mesaverde Group above and Dakota Group below. Some marine vertebrates and invertebrates and coal at several levels. Thickness 15-1500 m. Depositional environment: coastal marine, swamp, barrier bar, delta.

Kaiparowits Formation

Grey-blue, arkosic sandstone and shale, forms slopes and badland topography. Fossils include various reptiles, non-marine invertebrates, and plants. Thickness 180-360 m. Considered to be mainly a fluvial (river) deposit.

Wahweap Sandstone

Yellowish-grey sandstone and mudstone layers. Fossils very rare, include reptiles, invertebrates, and leaves. Thickness up to 360 m; usually 180-200 m. Depositional environment: fluvial (river).

Straight Cliffs Sandstone

Yellowish-grey, massive sandstone layers and mudstone. Land fossils (terrestrial vertebrates) rare in top part, marine and brackish water fossils in lower part. Thickness to 300 m. Depositional environments: fluvial (river) and coastal marine.

Tropic Formation

Grey shale with many buff-yellow sandstone beds, especially in lower part. Fossils include coal derived from plants as well as freshwater and marine invertebrates. Thickness to 380 m. Depositional environment considered to be marine.

Dakota Formation (Dakota Sandstone)

Yellow to white, brown to buff sandstone and darker carbonaceous shale and coal, partly conglomeratic. Fossils include coal, petrified trees, marine and freshwater invertebrates. Thickness to 30 m. Depositional environment: marginal marine, fluvial (river).

Cedar Mountain Formation

Grey to dark-grey shale with coarse Buckhorn basal conglomerate. Fluvial (river) and flood-plain paleoenvironment.

JURASSIC

Morrison Formation

Variegated mudstones, siltstone and yellowish grey-brown sandstones. Fossil dinosaurs, plants and freshwater invertebrates, fish, crocodiles, and primitive mammals present. Usually around 100 m thick, may reach 450 m. Depositional environment: fluvial (river), lacustrine (lake), floodplains, deltas.

Cow Springs Sandstone

Fine-grained quartz (mostly) sandstone, greenish carbonate cement. White to light-green, grey or buff in color, difficult to distinguish from Entrada. Fossils (none?). Thickness up to 200 m. Depositional environment: eolian (wind).

Summerville Formation

Crinkled, banded, or massive silty sandstone with some shaley members. Usually tan, grey, orange-red or buff in color. Fossils (none?). Thickness up to 100 m. Depositional environment: tidal flat, possibly some eolian (wind) deposits(?).

SAN RAFAEL GROUP (INCLUDES FIRST 4 FORMATIONS BELOW)

Todilto Formation

Cliff-forming grey limestone, shale, mudstone, and gypsum. Thickness up to 75 m. A few invertebrate fossils and fish. Commerical source of gypsum. Correlated with Curtis in Utah and Pony Express in Colorado. Was considered to be of marine origin, but now thought to represent evaporation in a salina (salt flat) with limited access to the sea.

Curtis Formation

Grey to white, roughly bedded limestone and thick gypsum. Marine fossils. Thickness usually 15 -75 m, up to 220 m. Depositional environment: marine, evaporite.

Entrada Sandstone

Light-red with white bands and reddish-orange, fine-bedded sandstone shale and gypsum. Fossils? Thickness usually 30-60 m, up to 180 m. Depositional environment: mainly fluvial (river) and eolian (wind).

Carmel Formation

Grey to buff limestone in beds alternating with softer, red, shaley layers, etc., some gypsum. More marine to the W. Marine fossils, vertebrates and algae. Thickness usually 30-60 m, up to 180 m. Depositional environment: generally considered to be marine, especially in W.

GLEN CANYON GROUP (INCLUDES FIRST 4 FORMATIONS BELOW)

Navajo Sandstone

Red, pink, orange, buff, grey, white, intensely cross-bedded sandstone. Occasionally with a thin layer of cherty limestone. Virtually no fossils except for a few tracks of dinosaurs, terrestrial reptiles, and plant remains. Thickness usually 30m, up to 670 m. Lower part has been considered Triassic. Depositional environment: mainly eolian (wind) and lacustrine (lake).

TRIASSIC

Kayenta Formation

Red-maroon, cross-bedded sandstone beds, with grey limestone and brown shale layers between. Fossils very rare, some freshwater invertebrates, wood, and vertebrate tracks. Trend is towards considering it Jurassic. Thickness usually less than 60 m, up to 365 m. Depositional environment: fluvial (river) and eolian (wind).

Moenave Sandstone

White to reddish-brown, cross-bedded sandstone and mudstone usually a massive cliff. Fossils include fish and crocodiles, very rare, vertebrate (dinosaur and other reptile) tracks. Thickness to 120 m. Depositional environment: eolian (wind) and fluvial (river).

Wingate Sandstone

Reddish, cliff-forming sandstone. Fossils very rare, some reptile tracks and remains reported. Thickness up to 200 m. Depositional environment: eolian (wind).

Chinle Group

Variegated mudstones, siltstones, sandstones, conglomerates and limestones. Several members including a prominent basal conglomerate called the Shinarump, which has a thickness of 20-40 m. Fossils include petrified wood (locally abundant as in Petrified Forest National Park), other plant remains, reptiles, etc. Thickness usually from 300-600 m. Depositional environment: fluvial (river) and lacustrine (lake). Was considered a formation, but the trend is to divide it into several formations.

Moenkopi Formation

Chocolate-brown to grey, gypsiferous sandstone and shale with gypsiferous and marine limestone members. Fossils include marine invertebrates and some tracks of land animals in other layers. Thickness up to 600 m. Depositional environment: marine, fluvial (river), tidal flat.

PALEOZOIC

PERMIAN

Kaibab Limestone

Grey-white, buff, dense-bedded limestone and dolomite, also with some sand and gypsum. Abundant variety of marine fossils including: fish, trilobites, sponges, brachiopods, rugose coral, gastropods, and scaphopods. Thickness 100 m at central part of Grand Canyon, up to 600 m elsewhere. Depositional environment considered to be an open and restricted ancient seaway.

Toroweap Limestone

Buff, reddish-grey limestone and sandstone with some gypsum layers, marine fossils as for Kaibab. Thickness 85 m at central part of Grand Canyon. Depositional environment assumed to be tidal flat, eolian (wind), marine, evaporite.

Coconino Sandstone

Buff, grey, cross-stratified sandstone. Fossils include locally abundant, mostly uphill, trackways of vertebrates and invertebrates. Thickness 100 m at central part of Grand Canyon, up to 300 m elsewhere. Depositional environment assumed to be a desert. Some data challenge this.

Hermit Formation

Deep-red, thin-bedded, shaly siltstone. Cracks to 5 m deep at top. Scarce fossils include some plants, trackways and insects. Thickness 70 m at central part of Grand Canyon, up to 300 m elsewhere. Correlates with Supai Fm. to the SW. Depositional environment: stream, dunes, coastal plain.

SUPAI GROUP (INCLUDES FIRST 4 FORMATIONS BELOW)

Esplanade Sandstone

Cross-stratified, reddish-brown sandstone units with thickness of 2-15 m, with mudstone or limestones between. Thickness 60-250 m. Some marine fossils, vertebrate tracks, and plant fragments. Assumed to have been deposited in a complex shoreline environment, including a fluvial (river) environment.

PENNSYLVANIAN

Wescogame Formation

Alternating quartz sandstone and intercalated red mudstone and some limestone that increases to the W. Has a lower cliff unit and an upper slope unit. Contact with the Manakacha below (hiatus — most of Middle Pennsylvanian absent) difficult to determine. Thickness about 30-200 m. Marine fossils mostly in limestones include fusulinids, pelecypods, and gastropods; also vertebrate trackways but no skeletal remains; some plant fragments. Depositional environment not well-defined, but assumed to have been by the sea but largely non-marine.

Manakacha Formation

Quartz sandstone and intercalated, red mudstone with great increase in carbonate content to the NW. Thickness 45-100 m; thickest in Grand Canyon region. Sparse fossils include plant fragments, brachiopods, bryozoans, pelecypods, gastropods, trilobites, and coral. The formation is assumed to have been deposited in a tidally influenced marine environment.

Watahomigi Formation

Consists mainly of red mudstone and siltstone and grey limestone and dolomite. Thickness in Grand Canyon from 30 m in E to 100 m in W. Fossils more abundant than in Manakacha include: brachiopods, gastropods, pelecypods, echinoderms, trilobites, sharks, forams, conodonts, corals, and plant fragments. The formation is assumed to have probably been deposited in a marine and adjacent-to-marine environment.

MISSISSIPPIAN

Surprise Canyon Formation

Appears as isolated lens-shaped exposures. It sometimes consists of a lower, dark-grey to red-brown clastic, terrigenous cherty deposit, and an upper, grey to brown-red marine carbonate. Best represented in the W part of the Grand Canyon. Thickness usually a few dozen meters, but up to 120 m. Fossils include: plants, coral, brachiopods, echinoderms, bivalves, cephalopods, trilobites, sharks teeth, and foraminifers. The formation is assumed to have been deposited in an ancient estuarine-stream valley system with a marine shoreline to the W.

Redwall Limestone

Grey to yellow limestone usually stained red from overlying layers. A large variety of marine fossils present including fish. Thickness 150 m in central part of Grand Canyon; slightly thicker elsewhere. Formation divided into 4 members in the Grand Canyon region. Depositional environment: shallow epeiric sea.

DEVONIAN

Temple Butte Limestone

Purplish limestone and dolomite. No clearly identifiable invertebrate fossils found (McKee 1976, p 53), possibly crinoids, corals, stromatoporoids and conodonts. Some fish discoveries made. Thickness 0-300 m. In central part of Grand Canyon, limited to small channels in Bright Angel Shale. Thickens W-ward. Depositional environment: tidal channels, subtidal and open marine.

CAMBRIAN

Muav Limestone

Grey limestone units with layers of mudstone, etc., between. Marine fossils not common, and include some brachiopods and trilobites. Thickness 30 m at central part of Grand Canyon, up to 250 m elsewhere. Depositional environment: shallow marine, intertidal and subtidal.

Bright Angel Shale

Greenish, shaley mudstone and fine-grained sandstone. Fossil brachiopods locally common, trilobites present. Thickness about 170 m at central part of Grand Canyon. Depositional environment: shallow marine, offshore.

Tapeats Sandstone

Brown-grey, coarse to medium cross-bedded sandstone forming a cliff. Fossils include trilobite trails and numerous "problematical worm borings" (McKee 1976, p 47). Thickness 70 m at central part of Grand Canyon, up to 180 m elsewhere. Depositional environment: shallow subtidal.

PRECAMBRIAN

In the Grand Canyon area, various layers of sedimentary deposits totalling 3600 m lie unconformably below the Cambrian. Fossils very rare, many questionable. Below these layers are igneous and metamorphic rocks.

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GLOSSARY OF SOME GEOLOGICAL TERMS

(Consult the "Introduction to Introductory Petrology" and the "Geologic Column" for rock and stratigraphic terms)

ALLOCHTHONOUS — originating from elsewhere, transported.

ANTECEDENT — pertaining to a stream that maintains its original course.

ANTICLINE — a fold which is convex upward.

AUTOCHTHONOUS — indicates no transport, *in situ.*

BACK REEF — the area between a reef and the mainland.

BALL AND PILLOW —a primary sedimentary structure characterized by hemisphere and kidney-shaped masses usually attributed to foundering.

BENTHONIC — said of an organism living on the ocean bottom, fixed or free.

BOUMA SEQUENCE — the characteristic sequence of complex sedimentary structures deposited by a turbidity current.

CARBONATE — a mineral formed in part using carbonate ions. Limestone is a common example, consisting of calcium carbonate.

CARBONATE COMPENSATION DEPTH — the depth in the ocean where the solution of carbonate exceeds the rate of deposition. Presently this is usually several thousand meters below sea level.

CATASTROPHISM — theory in which phenomena outside our present experience of nature have greatly modified Earth's crust by violent, sudden, but short-lived, events more or less worldwide.

CIRQUE — a steep-walled semicircular recess situated high on a mountain and produced by glacial erosion. It is commonly at the head of a glacial valley.

CLAST — the individual constituent of a sedimentary rock. It can be from clay size to boulder size.

CLASTIC — pertaining to rocks formed of clasts.

COLUMNAR JOINTING — forms parallel prismatic columns as a result of the cooling of magma.

CONCRETION — a hard compact mass of mineral matter in a sedimentary rock.

CONVOLUTE — wavy, disorganized, crumpled sedimentary layers, often occurring between parallel layers.

CORALLINE — pertaining to corals and related features of coral, such as reefs, etc.

CORDILLERA — an assemblage of mountain ranges with a general parallel arrangement.

CYCLOTHEM — a term applied to the repeat unit of a cyclic sedimentary sequence.

DEBRIS FLOW — a moving mass of a mixture of rock and mud with a dominance of the clasts being larger than sand size.

DENUDATION — erosion on a broad scale that results in uncovering the bedrock or a designated rock formation through erosion of overlying material.

DETRITUS — transported fragmental material derived from the breakdown of rocks.

DIAPIR — a dome or anticlinal fold, the overlying rocks of which have been ruptured by the squeezing out of the plastic core material. Diapirs in sedimentary strata usually contain cores of salt or shale; igneous intrusions may also show diapiric structure.

DISCONFORMITY — an unconformity where the bedding planes above and below the gap in deposition are essentially parallel.

ECOLOGICAL ZONATION THEORY — the theory that the sequence of fossils found in the geologic column is due to the ecological distribution of the organisms before the Genesis flood. The preflood ecological zones were destroyed in sequence by the gradually rising waters of the flood. The preflood ecology is assumed to have been different from present ecology.

EOLIAN — pertaining to the action or effect of wind.

EPEIRIC SEA — a sea within a continent or on the continental shelf.

EPIDERMIS FOLDING — folding of the epidermis (sedimentary layers or superficial cover layers) in contrast to a more stable basement which is not so involved in the folding.

EUSTATIC — changes in sea level that are worldwide, not local.

EVAPORITE — a nonclastic sedimentary rock composed primarily of minerals produced from a saline solution that became concentrated by evaporation of the solvent. Examples include gypsum, anhydrite, rock salt, chemically precipitated limestone, primary dolomite, and various rare nitrates and borates.

FACIES — the characteristic textures of a particular rock unit. May refer to rock type, fossil content, etc.

FAULT — a fracture plane in a geologic unit in which there is some observable displacement.

FLUVIAL — pertaining to, or produced by, a river or stream.

FLYSCH — a sedimentary deposit of thin units of marls, sandstones, conglomerate, graded deposits, often alternating in nature. May include turbidites.

FOLD — a bend in an originally planar rock structure.

FOLIATION — the planar structural features of a rock that result from the flattening of the constituent grains in the metamorphic process.

FORELAND — the stable area next to an orogenic belt towards which the belt was thrust. See **Hinterland**.

FORE REEF — the seaward side of a reef.

FORMATION — a group of rock strata or a body of igneous or metamorphic rock that has certain unique characteristics common to the unit and differing from adjacent units, usually of mappable size.

FOSSILS — any trace, imprint, natural cast or remains of a living organism preserved in sediments.

GEOLOGIC COLUMN — a composite diagram showing in one column a sequence of rocks corresponding to a chronological scale made according to the evolution of the fossils found in these rocks.

GEOSYNCLINE — an extensive elongated downwarped region of Earth's surface in which sediments and volcanic rocks have accumulated to great thicknesses.

GRABEN — an elongated trough bounded on both sides by high-angle normal faults dipping to the inside.

GRADED BED — a sedimentary layer which has the coarsest material at the base and becoming finer as one proceeds towards the top.

HIATUS — gap, missing layers in a sedimentary structure.

HINTERLAND — the area on the side of an orogenic belt away from the direction of the thrust. See **Foreland**.

HORST — an elongated block bounded on both sides by normal faults dipping to the outside.

INDEX FOSSIL — fossil used to date and to identify the strata in which it is found; a good index fossil is a species having a broad geographic range, a restricted stratigraphic range, a distinctive morphology and a relatively common occurrence.

ISOCLINE — a fold whose limbs are parallel.

JOINT — a fracture in a rock without displacement. It is often planar.

KARST — a type of topography formed on limestone due to dissolution forming sinkholes and caves.

KLIPPE — a transported block of rock that is isolated from its source either by sliding or by erosion of the thrust sheet from which it originated.

LACCOLITH — an intrusion of igneous rock with a convex upward roof and a flat floor.

LACUSTRINE — belonging to, or produced by, lakes.

LAMINA — very thin sedimentary layer, commonly in the mm range or thinner.

LITHOLOGY — physical character of a rock: color, mineralogic composition, grain size, etc.

LITTORAL — pertaining to the region between low water and high water, i.e., intertidal.

LOAD CAST — the bulbous projection of an overlying layer into the one below due to unequal loading.

MAGMA — molten fluid within Earth's interior formed from the melting of rock.

MATRIX — the finer-grained material filling the space between larger particles or fossils, etc.

MOLASSE — an extensive mixed sedimentary deposit resulting from the early erosion of a mountain range such as north of the Alps.

MONOCLINE — a local steepening of more horizontal sedimentary deposits.

MORAINE — accumulation of larger aggregates of unsorted glacial drift by the action of a glacier.

NAPPE — an extensive body of rock that has moved by recumbent folding or overthrusting.

NORMAL FAULT — fault in which the depressed block is above the fault surface, and the hanging wall has been depressed relatively to the footwall.

OOLITH (OOLITHIC) — a small (0.25 to 2 mm diameter) sphere whose center is usually a debris and whose shell is formed by concentric thin layers, usually of calcium carbonate.

ORGANIC REEF — a wave-resistant ridge or mound built by sedentary organisms showing relief above the surroundings.

OROGENY — the process of mountain formation.

OVERTHRUST — a near-horizontal thrust fault of wide extent usually many km^2.

PALEOGEOGRAPHIC DOMAIN — the location of a particular geologic area at a particular time in the past.

PALUDAL — pertaining to a marsh.

PALYNOMORPHS — a resistant, microscopic, organic body such as pollen, spores, acritarchs, etc.

PARACONFORMITY — an unconformity in which there is no erosional surface and the beds below and above are parallel, a non-sequence.

PARAUTOCHTHONOUS — not transported very far, intermediate between autochthonous and allochthonous.

PELAGIC — pertaining to the open sea but not the sea floor.

PENEPLAIN — a widespread featureless (flat) land surface presumably produced by long, continuous subaerial erosion.

PETROLOGY — the study of rocks.

PLATE TECTONICS — theory in which Earth's surface (lithosphere) is formed of rigid plates floating on the aesthenosphere. The different plates interact with one another at their boundaries, causing seismic and tectonic activity.

PROGRADATION — the outward or basinward migration of a shoreline and accompanying basinward sedimentation.

PSEUDO-OÖLITHIC ROCK — rock composed of small spherical pseudo-oöliths (oöliths without the defining internal structure). Sometimes with ill-defined outlines.

RECUMBENT FOLD — an overturned fold as in a nappe or other geologic unit.

REEF — a projecting outcrop of rocks.

REGRESSION — retreat of the sea from land areas.

RELIEF — unevenness of Earth's surface.

RETROGRADATION — the landward migration of a shoreline and its accompanying landward sedimentation.

REVERSE FAULT — fault in which the raised block is above the fault surface.

RIFT — a long, narrow continental trough bounded by normal faults; a graben.

RIPPLE MARKS — finely detritic sedimentary structures formed of sub-parallel elongated ripples, 1 to 5 cm high; produced by wind, water currents or wave action.

ROCHE MOUTONNÉE — smoothed off, mounded rock usually a few meters in size, produced by the action of glaciers.

SACCHAROIDAL — a rock texture term used for rocks having a sugary appearance.

SALINA — an area in which deposits of salt are found or formed.

SEDIMENTARY — formed by precipitation from solution, or as a result of transport by water.

SEDIMENTATION — processes leading to the formation of sediments: separation of rock particles, transport, deposition and finally consolidation of the particles in a new rock.

SEDIMENTS — any particles (of any size), laid down after some transportation by water, wind or ice.

SHEET — a large, widespread tabular mass of rock.

STRAND PLAIN — a prograded shore built seaward by waves and currents.

STRATA — plural of stratum, a stratigraphic unit. A stratum (or bed, layer) is a layer of sediments limited by two surfaces approximately parallel featuring sharp variations (visually obvious) in the structure of the sediments.

STRATIGRAPHY — science of the strata of Earth's crust, dealing especially with the characteristics, sequence of layers, and the time factors of this sequence.

SUBSIDENCE — gradual or sudden sinking of a large portion of Earth's crust.

SUPERPOSED — pertaining to a stream that maintained its course as it was established on a new lower surface.

SYNCLINE — a fold which is concave upward.

TALUS — rock fragments at the base of a steep slope or an extensive slope of such fragments.

TECTONIC — related to structural or orogenic features of Earth's crust.

TERRIGENOUS — originating from land surfaces in contrast to a marine origin.

THRUST FAULT — a fault whose surface is more horizontal than vertical and in which the direction of movement of the two parts is compressional.

TILL — heterogenous mixture of clay-boulder clasts resulting from the action of glaciers.

TRANSGRESSION — extension of the sea over land.

TURBIDITE — a sedimentary rock deposited by a turbidity current.

TURBIDITY CURRENT — a downhill, underwater density current consisting of a suspension of sediments. The current has a greater density than water, flows with a characteristic pattern, leaving a characteristic deposit.

UNCONFORMITY — an interruption in deposition in a sedimentary sequence. A gap in the stratigraphic record.

UNIFORMITARIANISM — theory stating that geologic processes operating today acted the same way and at the same speed in the past. This theory does not exclude some local catastrophes.

VARIEGATED — showing irregular variations in color.

VARVE — layer of sediment usually consisting of a coarse and fine portion, and thought to have been deposited during one year.

VERGENCE — the direction of inclination or overturning of a fold.

WILDFLYSCH — a kind of flysch characterized by large, usually unsorted blocks and contorted beds.

WRENCH FAULT — a lateral fault with a more or less vertical fault surface.

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