State University of New York at Cortland
Geology Department

GLY 262 Historical Geology

SPLIT ROCK QUARRY VIRTUAL FIELD EXPERIENCE

On this virtual trip you will collect and interpret geological information from the Split Rock Quarry — an abandoned limestone quarry located a few miles southwest of the city of Syracuse, New York. The rocks in Split Rock Quarry record the Late Silurian through Middle Devonian sedimentary succession of primarily carbonate rock that were deposited in an arid and warm setting at and near sea level of a very shallow inland sea. The quarry has been studied by geologists for well over 100 years and its well-preserved rocks and fossils tell a story of shifting environments across a tropical coastal seascape.

To complete this assignment, you will require web access and a personal computer with modern browser, where you will examine a series of digital images taken and different scales, short video clips, and larger-scale 3D models of the outcrop. You will be provided with a shortened list of images (of the 95 available) to examine and describe. You will use the observations of the images to characterize the different sedimentary rocks types, sedimentary structures, fossils, bedding and larger-scale features and place them within a paleoenvironmental context. Using scaled imagery, you will measure and log the strata to create a stratigraphic log, and interpret the depositional environments to develop a geologic history for the outcrop.

To complete this assignment, you will also need: (1) a printed copy of the outcrop panorama for note taking (which can be downloaded here), (2) a copy of the ICS Geologic Timescale (which can be viewed or downloaded from here), and (3) a ruler and a calculator.

BACKGROUND INFORMATION

Facies and Carbonate Depositional Environments

This virtual field experience examines a succession of strata (mostly limestone and some dolostone) that were deposited in an arid setting near the coast of a very shallow inland sea. Similar environments exist today in places like the Persian Gulf, coastal western Australia, the Bahamas, and Florida Bay.

In class we defined sedimentary **facies** as: *a body of sediment with certain characteristics indicative of a particular environment*. Thus, facies analysis involves the processes of ascertaining specific properties of sedimentary rocks that provide clues to the environments in which they were deposited. For the purpose of this study, we will be assigning the rocks into

three broadly-defined facies: (1) **Subtidal facies**, deposited below the mean low-tide mark, (2) **Intertidal facies**, deposited between the mean low and high-tide mark, and (3) **Supratidal facies**, deposited above the mean high-tide mark. A simplified graphical summary of each of these depositional environments and some diagnostic characteristics can be seen in Figure 1 below.
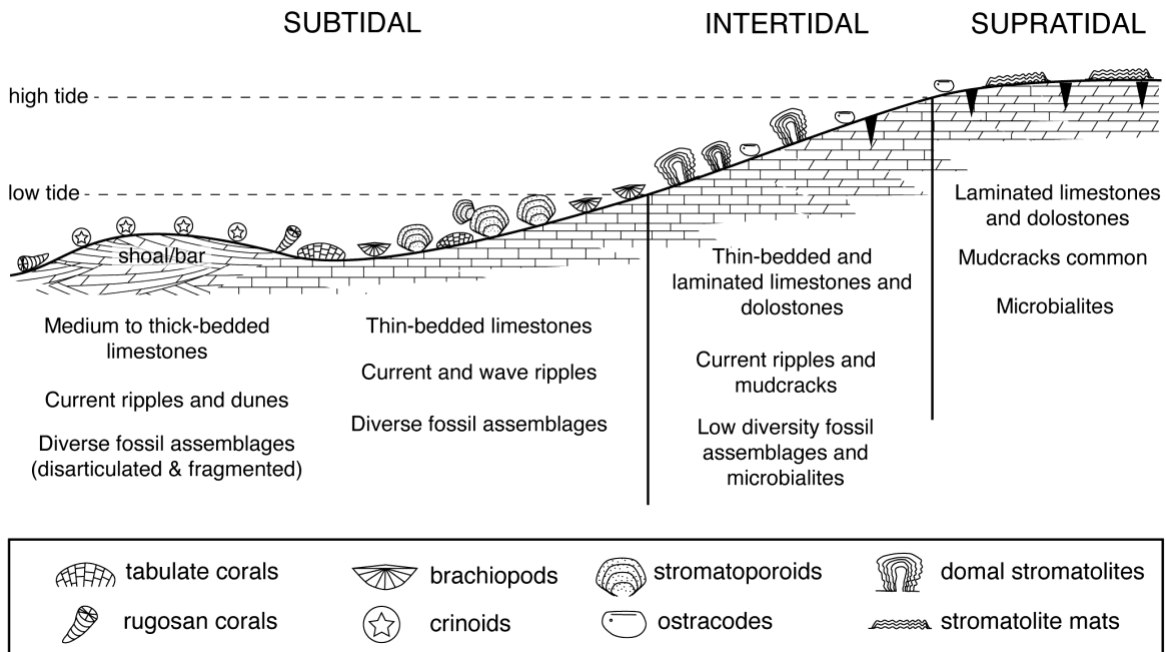
Figure 1. Simplified facies model for the Upper Silurian through Middle Devonian shallow-water carbonate environments in New York. Some common lithologic, sedimentary structures, and fossil attributes for each facies are provided. Not all features for each environment are listed. Modified from Laporte (1967, *AAPG Bull.*, v. 51).

Shifting Environments: Transgressions/Regressions and Walther's Law

As you have learned in class, environments shift over time due to a number of possible controlling factors including climate change and tectonic processes. It follows that sedimentary facies would therefore shift in response to shifting environments over time. Since the primary environmental variable in our above description is relative water depth (subtidal, intertidal and supratidal), the trajectory of environmental change on the Earth's surface would be either in a seaward or landward direction. A facies shift in the seaward direction over time results in a *transgression* at any one spot, while a landward shift in facies, would result a *regression*. Thus, during a transgression, normally exposed surfaces (supratidal in our case) become flooded (subtidal) over time. Conversely, during a regression, submerged sea floor (subtidal) becomes exposed (supratidal).

Recall that **Walther's Law** states that: in an uninterrupted stratigraphic sequence, laterally adjacent facies (across a land or seascape) will succeed each other in vertical succession (strata deposited over time). Applying the above depositional model (carbonate environments near sea level), Walther's Law would dictate that in an uninterrupted sedimentary succession, a body of strata indicative of an intertidal environment would be vertically succeed by *either* strata of the subtidal facies (representing a transgression due to relative sea level rise) *or* strata of the supratidal facies (representing a regression to relative sea level fall).

The importance of this principle is that it can be used to *predict* a sedimentary succession of changing facies. If a sedimentary succession does not conform to Walther's Law (e.g., two facies in vertical succession are not expected to be laterally adjacent), one would suspect the succession contains some sort of missing sediments, either due to a time interval of non-deposition, an episode of erosion of pre-existing sediments, or some combination of the two. Recall that a significant time gap, usually due to erosion, in concordant sedimentary successions (beds below and above the hiatus are parallel to each other) is termed aa disconformity.

VIRTUAL FIELD WORK

Reconnaissance and large-scale observations

Using the Gigapan image, take a few minutes to explore the outcrop. You should zoom in and out and pan left and right to get a sense of the total size and nature of the outcrop under study. Note, you should have already seen in the Gigapan image one or more of the scales (a thin pole that is 1.5 meters tall and with 10 cm red and white divisions).

Switch now over to the 3D model, take a few minutes to explore the outcrop using this tool. Note you can rotate the entire outcrop as well as zoom in and out.

You will now measure the stratigraphic thickness of the entire outcrop. There are several ways to do this using the Gigapan, 3D model and the individual Solocator images, but we will approximate it using the outcrop panorama image that your downloaded and/or printed. Find the Jacob staff (1.5 m tall scale) towards the right-center of the panorama. Using a ruler, measure (in mm) directly on the screen or on the printout how tall the Jacob staff is. Use this measurement to calculate the image scale. Note, such scale is only accurate where measured. Because of the depth perspective of the 2-dimensional photographic image, the scale will be inaccurate if measured on the more distant parts of the outcrop (scale decreases) or the closer parts of the outcrop (scale increases).

   Q1: What is the scale of the panorama image in millimeters per meter at the Jacob staff?

Now, starting at the bottom of the outcrop, beginning measuring with a ruler up the section making sure that your measurement is perpendicular to bedding. As you progress up the outcrop, you will need to move your measurements to the left where the upper parts of the outcrop can be seen. The best way to do this is to measure up to horizon (bedding plane) or surface in the outcrop that can be confidently traced laterally. After the lateral move, continue measure upwards until you reach the highest part of the outcrop (seen on the left-hand panel of the panorama.

Q2: About how tall (thick), in meters, is the rock exposure in from the bottom to the top the quarry?

Going back to the 3D model, let's explore the sequence of strata for some large-scale features. Zoom in a little bit and, with your mouse, rotate the model slightly so as you can clearly see the side view of the quarry wall and the step-like outcrop. From this view, you can see that the more resistant rocks will form outcrops and vertical surfaces whereas the less resistant beds for slopes and/or intervals covered with talus. These differences (in bedding and resistance to weathering) are actually a result of differences in the rock themselves including differences mineral composition and size of the particles, cementation and other properties.

Switching back and forth between the Gigapan and 3D model, explore the outcrop – from left to right and from top to bottom to get a sense of the changes in bedding, color or resistance to weathering and any other features that are observable from a distance. Now answer the following questions.

Q3: Does there appear to be a relationship between bedding thickness and weathering? If so, what is this relationship?

When geologists are faced with large outcrops or thick series of sedimentary strata such as this, it is useful to simplify the large amount of geologic data into smaller more manageable entities that are both identifiable and distinctive and may have formed under a similar set of depositional conditions. Subdividing rock strata also permit more precision in correlation. This is the reason we have named rock formations, just like why we have smaller divisions of geologic time.

Q4: If you had to subdivide the strata into 3, 4 or 5 different stratigraphic units (e.g., formations), what criteria would you use?

Q5: In the margins or center gap of the outcrop panorama, label these stratigraphic units (1, 2, 3, etc.) and draw little tick marks where you would separate them.

Q6: If you had to make an educated guess, what type of rocks make up most of the exposed outcrop?

Q7: Where and in what sorts of depositional environments do these rock types most commonly form?

The above questions were answered from the large-scale Gigapan image, 3D model and static panorama. These responses to Q3 through Q7 above are *hypotheses* that need to be tested. We will do this by looking at close-up images and videos.

Sample Observations

To navigate to the designated images/videos, you will need to begin at the outcrop map pages (north side and south side), click on the designated hot-linked rectangle to go to the corresponding Solocator image (labeled A-P). From a Solocator image, click on the appropriate enumerated and hot-linked number to bring up the close-up image or video.

For each sample listed in Table 1 (located at the end of this assignment sheet), you are asked to record a number of observations as best determined from the close-up images and videos. These include rock names (e.g., limestone, dolostone, sandstone, shale, etc.), observed sedimentary structures (e.g., ripple marks or mud cracks), and fossils as best can be determined (see Figure 3 for the fossil guide). Not all samples will contain visible sedimentary structures or fossils. The column on the far right of the Data Table is for facies and is your *interpretation* of the environment of deposition (recorded as supratidal, intertidal of subtidal). Determination of facies should be based on the observations in the other columns (rock types, sedimentary structures, and fossils). Do notice that in Figure 1, there is potentially even finer subdivision of the subtidal facies into a shallow subtidal depositional environment and a higher-energy shoal of off-shore bar. This distinction may be helpful later in the activity.

Q8: Complete Table 1.

Now that you have identified a number of samples and determined to which facies the samples belong (in Table 1), it will be necessary to determine where the changes from one facies to another occur in the outcrop.

You will need find the position (height) in the stratigraphic succession where one facies passes into the next overlying facies. To do this, you will go to the Solocator image containing one of your identified facies (in Data Table 1) , then, systematically, review the next higher image/video. If this appears to belong the same facies, go to the next higher up image/video. Continue through the images/videos until you have a sample that belongs to the different facies. In some instances, you can see the facies change within in a single image.

> **Q9**: In the side margins or gap in the middle of the outcrop panorama, label the occurrence of facies as can best be determined Draw little horizontal tick marks where you would separate the facies. You will use these marks later when developing your stratigraphic log.

> **Q10**: How do these subdivisions compare with the your initial hypotheses on stratigraphic units (in Q5)?

Depositional (sedimentation) rates and geologic time

While there are certainly many factors that control sedimentary depositional rates (e.g., sediment supply, sea-level changes, and the rate of seafloor subsidence) and such rates are quite variable even within similar depositional settings, average values from similar settings are on the order of about 1 mm sediment deposited per year (1 mm/yr).

> **Q11**: Using the above depositional rate and the outcrop thickness you determined in Q2, calculate the amount of time (in years) that might be represented in the outcrop. Please show all of your work.

The above calculated estimate of time makes several critical assumptions. The primary assumption is that the depositional rate is constant through the entire outcrop and that all time is represented by sediments. From modern carbonate producing environments, it is known that this assumption is *almost never* met and that there may be intervals of time with higher sedimentation rates and other time intervals in which little or no sediment was deposited or in some cases even removed.

An addition assumption with calculating the average depositional rate is that the succession of strata is complete and that no strata (once deposited) were removed by erosion.

The lowermost layer of the quarry (present in the quarry floor) has been determined to have been deposited in the Pridoli Epoch close to the Upper Silurian-Lower Devonian boundary.

> **Q12**: According to the ICS Timescale, what is the chronological age (in millions of years before present) of the Upper Silurian-Lower Devonian boundary?

The uppermost layer rock exposed in the quarry has been determined to have been deposited close to the Lower-Middle Devonian boundary.

> **Q13**: According to the ICS Timescale, what is the chronological age (in millions of years before present) of the Lower-Middle Devonian boundary?

> **Q14**: Using these dates, calculate the *observed* time range (rounded to the nearest 10^6 yrs) between the lowermost and uppermost parts of the outcrop. Show all of your work.

> **Q15**: Using this time range and applying the sedimentation rate of 1 mm/yr, approximately how thick (in meters) would you have expected the stratigraphic succession to be if all assumptions are met? Again, please show all of your work.

> **Q16**: Based on what you know about depositional processes and the principles of strata, how might you explain the difference in the two numbers—that based on thickness and that based on ages (there are two obvious choices)?

Q17: Looking back through the Solocator and closeup images you examined in Data Table 1, what structures and features might suggest that one of the above choices is the more likely? Please indicate what specific evidence (and from which image or images) best demonstrate this.

Stratigraphic Column

The last part of this activity will be constructing a stratigraphic column of the outcrop. A stratigraphic column is a to-scale drawing by a geologist that describes the sedimentary rocks that are present in a stratigraphic succession. This allows other geologists, who have never seen these rocks in person, to understand the stratigraphy and geology of that area. You are asked to draw a stratigraphic column which depicts the succession of rocks, the position of fossils and sedimentary structures, and facies. Essentially, your stratigraphic log will depict some of the changes you observed in rock types and bedding (see Q3–Q5) and the interpretation of facies (Q8–Q9). A template for the stratigraphic column provided at the end of this document.
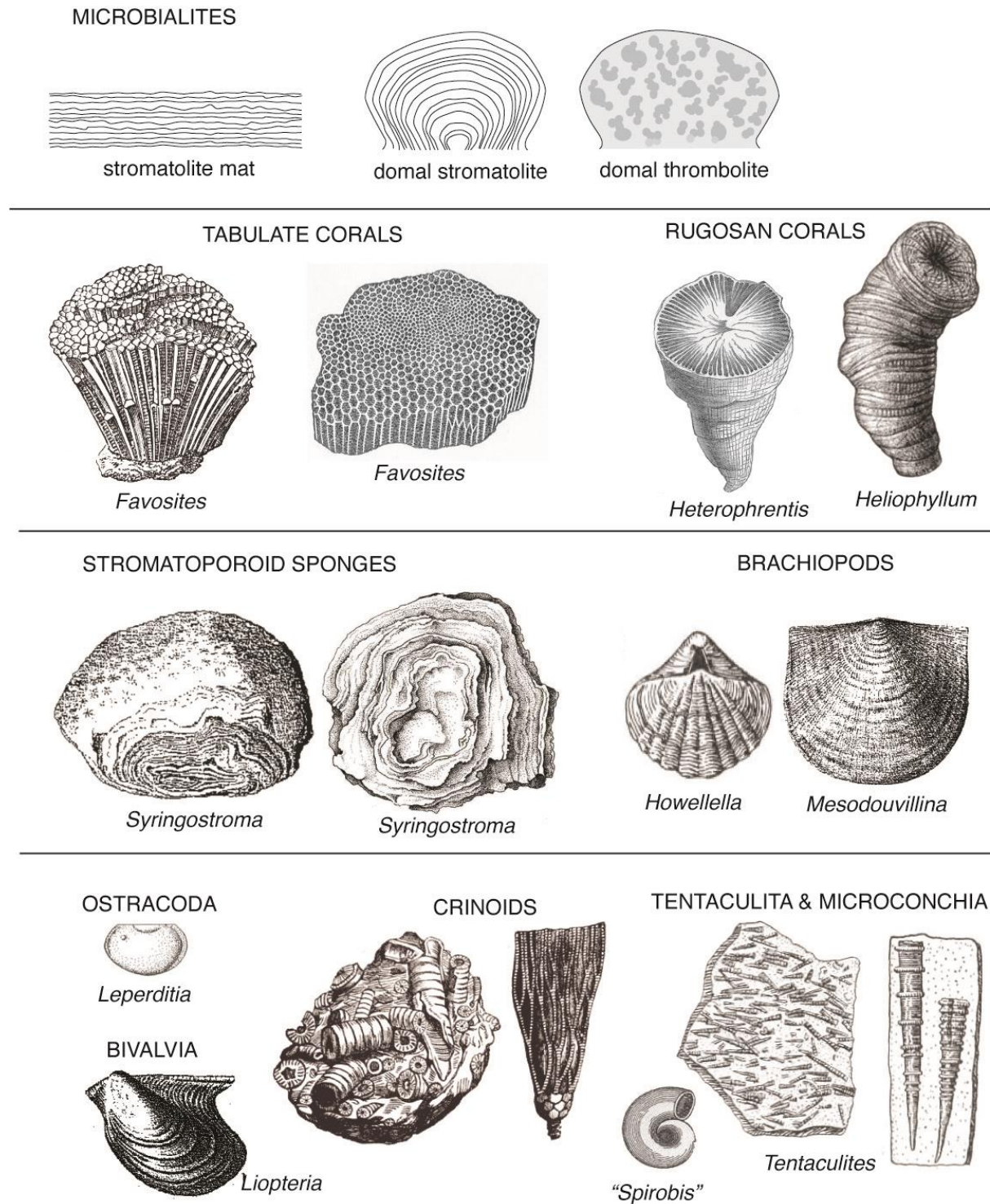
A few helpful tips…

1. Using your total thickness from Q2, pick an appropriate scale for the stratigraphic log trying to utilize (fill up) the entire space in the log. Place tick marks in the height in meters column at every meter.

2. Note that the 0 m mark should equal the quarry floor and that there is some room in the template to include some of the rocks below (those of Solocator A).

3. Based on your response regarding changes in bedding and transition between facies (Q9) transfer the position (height) of the tick marks to the log template to guide your drawing.

4. The lithology column represents rocks type(s) and will also show some large-scale features like bedding and weathering. Your column should represent how the section looks in the field.

5. Begin the lithologic column by freehand drawing the right edge of the lithologic column to, as close as you can to match the weathering profile in the outcrop – have your profile stick out to the right for resistant beds/intervals.

6. Fill your lithologic column with the appropriate lithologic fill patterns and use small symbols to represent fossils and sedimentary structures in their appropriate column (see Figure 4)

7. If you believe you have a disconformity, draw a squiggly line horizontally across the entire log at that position (height).

8. The sea-level column should be completed with a thick line. If there is a disconformity in the succession, it is okay to have a horizontal jump in the sea level curve.

9. In the remarks column, please describe the observed properties that define your facies.

Figure 3: Common Fossils from the Upper Silurian through early Middle Devonian of Central New York

MICROBIALITES

stromatolite mat   domal stromatolite   domal thrombolite

TABULATE CORALS   RUGOSAN CORALS

Favosites   *Favosites*   *Heterophrentis*   *Heliophyllum*

STROMATOPOROID SPONGES   BRACHIOPODS

Syringostroma   *Syringostroma*   *Howellella*   *Mesodouvillina*

OSTRACODA   CRINOIDS   TENTACULITA & MICROCONCHIA

Leperditia

BIVALVIA

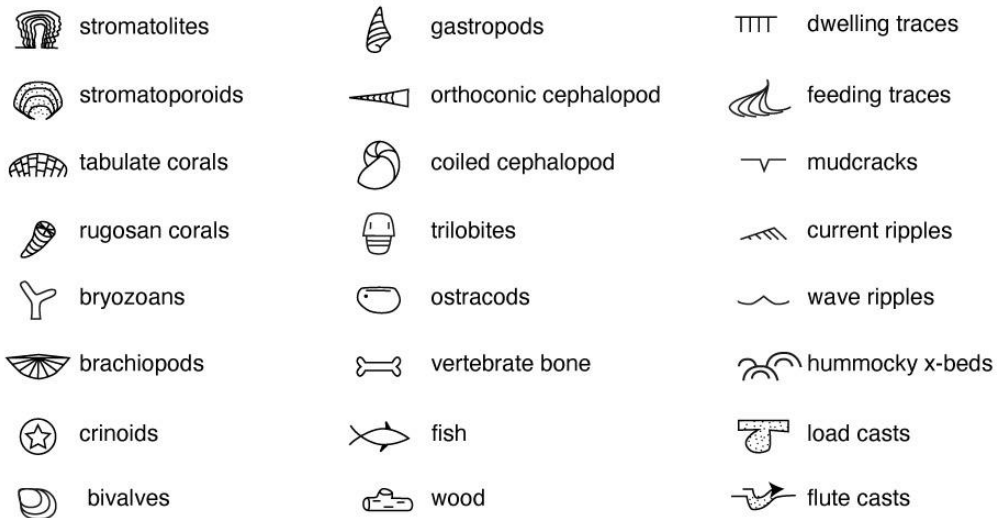*Liopteria*   "*Spirobis*"   *Tentaculites*

Figure 4. Commonly used fill patterns and symbols for lithology, fossils and sedimentary structures used in stratigraphic logs.

Lithologic Fill Patterns

Conglomerate	Breccia	Sandstone	Bedded sandstone	Crossbedded sandstone
Ripple-bedded sandstone	Shaley sandstone	Calcareous sandstone	Interbedded sandstone and shale	Siltstone
Shale	Calcareous shale	Carbonaceous shale	Interbedded limestone and shale	Limestone
Crossbedded limestone	Dolostone	Dolomitic limestone	Cherty limestone	Coal
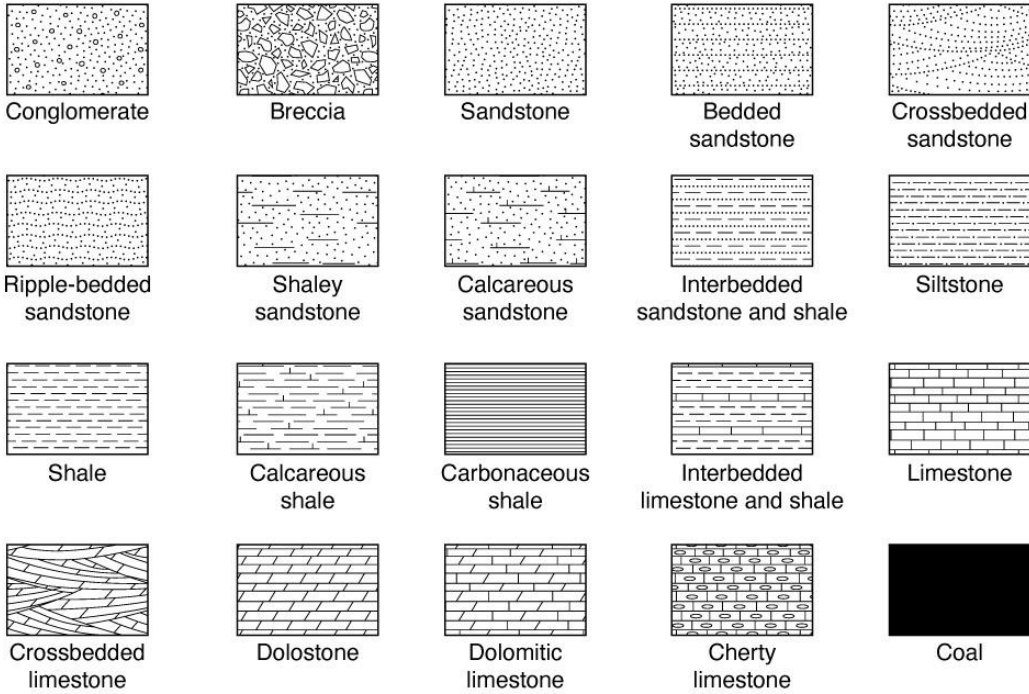
Symbols for fossils and sedimentary structures

stromatolites	gastropods	dwelling traces
stromatoporoids	orthoconic cephalopod	feeding traces
tabulate corals	coiled cephalopod	mudcracks
rugosan corals	trilobites	current ripples
bryozoans	ostracods	wave ripples
brachiopods	vertebrate bone	hummocky x-beds
crinoids	fish	load casts
bivalves	wood	flute casts

DATA TABLE 1. RECORDED OBSERVATIONS AND FACIES INTERPRETATION

Image/ Video	Rock Name(s)	Bedding & Sedimentary Structures	Fossils	Facies
AV1/A1				
K1				
K2/K3				
B2				
B3				
CV2				
C3				
C5				
D2				
D5				
E3				
EV1				
M3				
M5				
O2				
F2				
F4				
F8				
G2				
G3				
H2				
H3				
H4				
H6				
HV1				

Graphic Stratigraphic Log

HEIGHT (m)	LITHOLOGY	weathering profile	SED STRUCT.	FOSSILS	REMARKS	SEA LEVEL		
						subtidal	intertidal	supratidal
0								

Name: