GO THERE—MYSTERIES OF LOCH NESS, SCOTLAND

Use ***FLY TO*** and enter *Loch Ness, Scotland* as the destination. The view will settle in at about 15 miles ***EYE ALTITUDE***, centered about midshore on the northeast coast of the Loch. Note how the cursor (cross-hairs) is labeled *Loch Ness, United Kingdom* in the ***VIEW WINDOW***. Describe the shape and orientation of *Loch Ness* based on this view in the box below.
Does the shape of the *Loch* remind you of other bodies of land-based bodies of surface water, and if so what kind? Based on this observation and comparison, describe whether or not the water in the lake is predominantly stationary or rapidly flowing, and give reasons for your arguments in the box below.
Without using the ***ZOOM*** feature, use the ***HAND CURSOR*** and sweep across the lake and along its axis and to determine the average elevation of the lake. Remember that *Google Earth*® uses an averaging mechanism of regularly spaced coordinates to generate elevations, and that the apparent elevation of the lake is affected by elevations along its shoreline. Record and interpret your findings below.
Go to the ***LAYERS WINDOW***, and make sure that the ***WATER BODIES LAYER*** is checked in the folder of Geographic Features. In the box below, what do you suppose, based on the other labeled water bodies in the area, the word *Loch* means?
Turn off the ***WATER BODIES LAYER***. The outlines of the ***WATER BODIES LAYER*** does not directly overlie the images used as the base for ***GOOGLE EARTH®*** in the ***VIEW WINDOW***. ***ZOOM OUT*** to between 22 and 25 miles ***EYE ALTITUDE***. *Loch Ness* should be fully displayed in the ***VIEW WINDOW*** at that ***EYE ALTITUDE***. Describe the orientation of the *Loch* with respect to the cardinal directions (i.e. north, south, east, west).

Using the ***LINE TOOL*** version of the ***SHOW RULER*** tool, measure the length of the *Loch* along its axis from its green southwestern terminus to the brown beach/shore at its northwesternmost point, just northeast of the small hamlet of *Lairgmore*. Record your observation below.
The width of the *Loch* is fairly constant, except for the stubby bay (*Urquhart Bay*) located at the junction of the *Loch* and *Glen Urquhart*, and the tapered end of the *Loch* at its southwestern terminus. *Glen Urquhart* is the valley or "*glen*" that houses the village of *Drumnadrochit*, and the famous *Urquhart Castle* on the shores of the *Loch*. Archeological evidence suggests that the current site of the castle has been the site of one of the major fortresses in Scotland such since the latter half of the sixth century. Using the ***LINE TOOL*** version of the ***SHOW RULER*** tool, determine the average width across the longitudinal axis of *Loch Ness*. Measure its width at several (at least three) representative sites, and record your observations in the space below.
Loch Ness is the second largest lake by area in all of the *United Kingdom*, surpassed only by *Loch Lomond* to the south southwest. However it contains more water than *Loch Lomond*, and more fresh water than all of the surface water in *England* and *Wales*. Just how much is that? *Loch Ness* averages 600 feet (0.114 miles) deep—it's a dang deep lake, the second deepest in *Scotland*. With a surface elevation of about 50 feet, the freshwater at the bottom of the lake is over 500 feet below sea level! The bottom drops to over 500 feet within about 50 feet of its southeastern shore line near *Foyers*. In order to estimate how much water is in the lake, think of it as a long rectangular box. Multiply its length by its width and its depth. Calculate the volume first in cubic miles, and record your calculations and answers below. Make sure that units you use for length, width and depth are all the same (should be in miles or fractions thereof).
Calculate the volume now in cubic feet, making sure to use to either convert your length, width and depth measurements (in miles) to feet by multiplying each measurement by 5280 and then multiplying the converted length, width, and depth values; or by remeasuring on ***GOOGLE EARTH®*** in feet; or by multiplying your cubic mile estimates by 5280^3. Record you calculations and determinations below.

Now convert your volumes to units that we can picture a little more easily, and complete the chart below. Some of those units include gallons, and acre feet, and one just for you, backyard pools. An acrefoot of water is the amount of water it takes to cover one acre of land with one foot of water, or about 325,851 gallons (about a third of a million gallons). An average backyard swimming pool about 5 feet deep by 20 long, by 13 feet wide will hold around 10,000 gallons. That means that draining about 33 pools completely over one acre will only cover it with one foot of water. An American football field is an area (including end zones) about 360 feet long and 160 feet wide (57,600 ft^2), just slightly larger than one acre of land (43,560 ft^2). One square mile is exactly 640 acres, or just about the same number of football fields.

There are many ways to make the conversion. My suggestion is to use one of the free conversion websites. Simply *GOOGLE™* search "conversion factors", and follow the directions. Then complete the table below

				20'x13'x5' (1300 ft^3) ~10,000 gals	One acre flooded with 1 ft water	1 ft deep	1 ft deep 27878400 cubic feet
Cubic miles	Cubic feet	Cubic meters	gallons	Backyard Pools	Acre feet	Flooded Football Fields	Flooded Square Miles

How does the volume of water in Loch Ness in acre feet compare with the total area of Scotland (20,166,400 acres)? How much of Scotland would be covered by one foot of water?

In 2004, the per capita domestic (non-agricultural and non-industrial) water consumption in the United Kingdom was around 88 gallons/day (334 liters/day), while US per capita domestic consumption was about 153 gallons/day (578 liters/day) (data retrieved from http://www.infoforhealth.org/pr/m14/m14chap2_2.shtml, and European Schoolbooks (ES). 1994. The Battle for water: Earth's most precious resource, p. 1-160). Hypothetically, if all of the water currently in Loch Ness could be used for domestic use only, How many days would all of the water Loch Ness support the domestic/personal water requirements of the entire United Kingdom, current (July 2007, CIA World Factbook https://www.cia.gov/library/publications/the-world-factbook/geos/uk.html) estimated population 60,776,238? The question is only hypothetical—all of the water is not usable; the total water use is vastly higher because industrial and agricultural use greatly exceeds domestic use; the model doesn't account for fluctuations in evaporation rate, surficial and groundwater recharge; the model doesn't include inherent changes in population structure and water use; and it is impossible to distribute the water to all fractions of the UK populace. Document your calculations and answer the above question in the space below. .

In the ***SEARCH WINDOW***, use the ***FLY TO TAB*** and type in the coordinates *56 57 30.07 N, 4 55 41.20 W*. ***GE*** will center your view over the center of *Loch Lochy*, about 16 miles southwest of *Loch Ness* at an ***EYE ALTITUDE*** of slightly over 3000 feet.. ***ZOOM OUT*** to around 10,000 feet ***EYE ALTITUDE***, then ***TILT*** your view to the side about 30 degrees off the horizontal, and ***ROTATE*** the view direction so that you can look northeast along the axis of *Loch Lochy*. Describe the shape and ruggedness of the valley in which *Loch Lochy* is situated. What does that imply about the *Great Glen* in which *Loch Ness* is situated, and the shape of the bottom of *Loch Ness*?

How high are the walls of the *Great Glen* in the *Loch Ness* area? Sweep the hand along the top of the ridge marking both the north and south walls of the *Great Glen* between about *Foyers* and *Urquhart Castle*, and record your average elevation for each in the table below. Also sweep the hand along the axis of *Loch Ness* to determine its average elevation. The relief (difference in elevation) of the *Great Glen* is not much different along its entire axis. Determine the relief by subtracting the elevation of the *Loch* from the elevation of the north and south walls of the *Glen*, and record your calculations and observations in the space below.

Along Loch Ness	Average Elevation	Elevation of *Loch Ness*	Relief of the *Great Glen*
North wall	+		
South wall	+		

The u-shaped or rounded cross-section of the *Great Glen* is similar to valleys carved by flowing glaciers at the high latitudes and high elevations of our planet. Glacial ice plastically glides across the Earth's surface, scraping and abrading the bedrock with rock debris "frozen" into its base as it slides away from sites of ice accumulation. The glacial ice usually seems to channel itself along a pre-existing v-shaped valley or other weak area of Earth's bedrock, and in the process creates a rounded trough-like channel.

The elongate lochs of the *Scottish Highlands* north of the *Great Glen*, and elongate lochs in the *Grampian-Argyll Mountains* to the south (which include *Ben Nevis*, the highest mountain in the *British Isles* (summit @ 4406 feet) just southeast of *Fort William* at the southern terminus of the *Great Glen*) seem to fill u-shaped troughs between the Scottish crags and *munros*.

How many of these elongate lochs (over about five miles in length) can you count **NORTH** of the *Great Glen*? Make sure you turn on the ***WATER BODIES LAYER*** in the ***LAYER MENU*** as it makes them easier to count. You should also turn on the ***SCALE LEGEND*** in the ***VIEW MENU*** to help you determine their length.

How many elongate lochs (over about five miles in length) are found **SOUTH** of the *Great Glen*?
Now examine the general nature of the erosional landscape of the *Highlands* north of the *Great Glen*, and the *Grampian Mountains-Argyll Region* south of *Great Glen*. You should ***ZOOM IN*** and ***"FLY"*** across the landscape of each area, usually with about 30 degrees of ***TILT*** to really "see" the topography. Which area *Highlands* or *Grampian-Argyll*, has the most cuspate, serrated ridges and bowls, and gouged u-shaped valleys?
What do the observations you just made suggest about the magnitude of glacial erosion in these two areas of *Scotland*? Why do you think that is so?
How do the shapes of the valleys of *Loch Aber* and *Loch Linhe* (elongate "bays" southeast of *Great Glen*), as well as the valley of *Loch Leven* (due east of the northeastern terminus of *Loch Linhe*) compare with the shape of the *Great Glen*?
Because those valleys are now filled with marine water, what does that tell you about the depth of the sea when glacial ice carved them?
How does that explanation help explain the freshwater depth of *Loch Ness* (over 500 feet below sea level)?
Where might you logically hypothesize that the water in the sea "went" when the glaciers carved this landscape?
Where might you hypothesize the glacial ice "went" when the scoured valleys were uncovered from their frozen blankets?

Where and what type of other evidence might you search for using **GOOGLE EARTH**® to verify your hypotheses?
Determine the average elevation of *Loch Oich* to the northeast (elev = _____) with *Lochs Aber* and *Eil* to the southwest (elev = ____and complete the table below. Does water from *Loch Lochy* naturally flow into *Oich* and ultimately into *Ness* to the north? You may have to **ZOOM IN** to about 3000 feet **EYE ELEVATION** on these lakes to make the measurements.

	Loch Linhe	*Loch Aber*	*Loch Eil*	*Loch Lochy*	*Loch Oich*	*Loch Ness*
elevation						
Marine-influenced or fresh						

Hypothetically, if the local residents of *Loch Ness* poison the lake and kill the monster, would the poisoned water flow out the *Caledonian Cana*l from *Loch Ness* into *Loch Oich*, or would the water most likely flow out the five mile *River Ness* towards the *North Sea* at *Inverness, Scotland*? In other words, in which direction does the water from *Loch Ness* ultimately flow?
At the southwestern terminus of *Great Glen* at *Fort William*, use the **SHOW RULER TOOL** to draw a line along the axis of the *Great Glen* from *Fort William* at its southwestern coastal terminus (*Loch Aber* is really part of the ______, as you already determined) to its northeastern coastal terminus at the mouth of the *River Ness* in *Inverness*. How long is the *Great Glen* in miles, and how straight does it appear to be?
Does the structure on which the *Great Glen* formed appear to end at its coastal termini, or does it simply disappear at the sea shore? What is the evidence that you can see to support your conclusion, and give a definition of where, based on that evidence, you would place the termini of this foundational structure?
Have you seen any or do you know of any other structures on Earth that are that straight and that long? If so, compare/contrast them to the *Great Glen*.

Using the controls, move the ***VIEW WINDOW*** at an ***EYE ALTITUDE*** between 30 and 45 miles to view the area just north *Lismore Island*, of the *Inner Hebrides* near the mouth of *Loch Linhe*. This area is cradled by bays just north of *Lismore Island*, and the *Isle of Mull*. This prominent starkly unvegetated pink-tan granitic peninsula holds some clues about the extremely linearity of the *Great Glen*. The peninsula bound at the west by the channel separating it from the *Isle of Mull*, and the estuarine *Loch Sunar*t to the north appears starkly unvegetated, typical of easily weathering granitic rock, forming a crumbly granitic "soil" often called "*grus"*. Plants have a difficult time rooting themselves into decomposing granite. These granitic rocks are referred to as the *Strontian* Granites for the small village *Strontian* on the northern shore of *Loch Sunart*. Rock units such as this are conventionally named for a geographical feature near where they crop out onto the surface of the Earth. Print this view and attach it to this assignment. Label the Peninsula "*STRONTIAN GRANITES*"
Great Britain has relatively few rocks suitable for high-quality aggregates, which are necessary components of concrete, roadfill, ballast, and other construction activities. The aggregate industry in *Scotland* relies on the presence of igneous rocks, and in 1995 totaled over £190 million (i.e. $323 million dollars US) see http://www.scotland.gov.uk/Publications/2007/06/04121253/1 retrieved 12/06/07). The *Strontian* Granite at *Glensanda* is one of the most important aggregates in *Great Britain*, and is shipped as far south as *Southhampton, England*. It is the largest quarry in Europe, and produces over 7 million tons of aggregate per year and employs over 200 workers (Lovejoy, 2007). The cost of shipping/transportation is the major expense determining the worth of aggregate, which attests to the significance of the *Strontian* Granite. Use ***FLY TO*** in the ***SEARCH WINDOW***, and type in *Glensanda, Morvern, Oban, Scotland* and enter ***GO***. The view will settle on about 3000 to 3300 feet elevation, and should be fuzzy. ***ZOOM OUT*** to an ***EYE ELEVATION*** about 30,000 to 35,000 feet. In the box below, explain why the quarry workings (include the mining roads) are white in this view.

The *Strontian* granites were formed around 425 to 430 Ma (millions of "years") during the Silurian Period of the Paleozoic Era, based on geochemical and geological evidence. Geological evidence suggests that these granites formed from magma generated during the *Caledonian* mountain-building event or Orogeny (latin "*oro"* = mountain, "*geny*" = origination), long before glaciers covered northern *Scotland* and even before dinosaurs ever roamed the Earth. Granitic rock is not layered (observe the peninsula), and forms from solidification of sticky, viscous, silica-rich magma deep (miles) below the surface of the Earth. The magma eats its way towards the surface, but is so thick and sticky it often looses all of its upward "thrust" and simply "chills" and crystallizes inside the crust. Such magma is commonly generated where seafloor or oceanic crust is thrust underneath continental crust, and this type of boundary is often referred to as an oceanic/continental subduction zone. This type of activity also changes the rocks into which the magma intrudes, metamorphosing and recrystallizing them, as well as the pressure of collision of two plates of crust which reorients, and fractures the rocks into which the magma intrudes.

The nature of granitic intrusions, now exposed through erosion of the rock that trapped them, is that they are usually like large blobs of paint, which instead of dripping down, rise up. And the minerals and chemistry of these blobs is like a fingerprint—blobs formed at the same place at about the same time have the same chemistry, and other blobs just don't match.

Use ***FLY TO*** in the Search window and type in *Foyers, Scotlan*d, and enter ***GO***. The ***VIEW WINDOW*** should center in at an ***EYE ALTITUDE*** of around 4300 feet. ***ZOOM OUT*** to an ***EYE ALTITUDE*** of about 30000 feet plus or minus a couple thousand. The view shows the small constructive fan delta built out into *Loch Ness* by the *River Foyers*. *Foyers* is a small village on the south central of shore of *Loch Ness* built around the mouth of the *River Foyers*. The *Falls of the Foyers*, is a spectacular steep waterfall and prominent tourist attraction. *Foyers* is also the site of one of the first aluminum smelters in *Britain* (1894-1967), and the water in the *River Foyers* was diverted to run a hydroelectric system necessary for smelting aluminum from bauxite and other ores of aluminum (Stratton et al., 2000). In the box below, describe the shape of the *River Foyers*, and determine in which general direction the river flows?

For our purposes, the *Foyers Granite*, which is a brecciated outcrop exposed on the banks of the *River Foyers*, gives us clues about why the *Great Glen* is so straight, and for the origin of underlying foundation for the *Great Glen*. The *Foyers Granite* has essentially the same mineralogy, same geochemistry, the same structures and paleomagnetic properties, and formed at the same time as the *Strontian Granites* to the southwest on the other side of the *Great Glen*. In other words, they have the same "fingerprints". What does this imply about the large "rip" in the Earth we call the *Great Glen Fault* (GGF), and can you describe the nature of how this "rip" originated in the box below? What is its relationship in time to the *Strontian* and *Foyers* granites?

Use the ***SHOW RULER TOOL*** to measure the distance in miles from the point where the cross-hairs are situated in *Foyers* to the southwesternmost tip of the Peninsula where the *Strontian Granites* are exposed at the mouth of *Loch Linhe*. What is the distance, and what does it imply about the magnitude of movement of the *GGF*? Does the implied movement match the kind of tectonic movement that generates granitic magma (e.g. convergence and subduction), or has there been a change in the direction and type of underlying movement and stress that generated the *GGF*? Record your measured distances and comments in the box below.
From *Foyers*, if you look directly across the *GGF*, in which general direction (to your left or to your right) has the original granitic mass been transported? Record your observations in the box below.
This type of fault is referred to as a *sinistra*l transform or left-lateral strike-slip fault. *Sinistra*l is a latin-based synonym for “left” and refers to the apparent direction of offset you observed of the granitic mass on the north side of the *GGF*. The opposite of *sinistral* in latin is *dextral*, or “right” Strike-slip is used to describe faults in which most of the movement (i.e. slip) is laterally along the faults surface, and not vertically as in a dip-slip fault. Transform is a synonym for strike-slip, implying lateral not vertical shifting along the fault. Other significant strike-slip faults globally include the *San Andreas Fault* system (*SAF*) of *California*. The *SAF* is over 800 miles long and is currently tectonically active, and responsible for major high-magnitude earthquakes that have rocked *California* in historic time (e.g. 1857, 1906, 1989). If you were to look across the *SAF*, identifiable rock masses (similar to the *Strontian* granites along the *GGF*) are shifted to the right at least 300 km (see Rallen, 2004 in references), and the shifting on the SAF began around 24 Ma (i.e. about 24 million years ago in the early Miocene Epoch)(Sims, 1993). Based on the reversed offset of rocks along the *San Andreas Fault* when compared to the apparent lateral shift of rocks along the *Great Glen Fault* in *Scotland*, to what type of fault would the *San Andreas* be referred?

NAME:____

In conclusion, list the similarities and differences of the *SAF* in *California* and the *GGF* in *Scotland* in the box below.

	Great Glen Fault	San Andreas Fault
When it formed = age		
How it formed		
Current activity		
Subsequent modification by natural causes		

References

Anderson, J.G.C., and Owen, T.R. 1980. The Structure of the British Isles, Second Edition. Pergamon Press, Oxford. 251 pp.

Central Intelligence Agency. 2007. CIA World Factbook –United Kingdom. Accessed July, 2007 at https://www.cia.gov/library/publications/the-world-factbook/geos/uk.html.

European Schoolbooks (ES). 1994. The Battle for Water: Earth's Most Precious Resource. Cheltenham, United Kingdom, ES. 1994. p. 1-16.

Highly, D., Cameron, D., Lusty, P., Browne, M., Norton, G, and Rayner, D. 2007. Igneous rock: Geology and mineral planning factsheets for Scotland, part 1. produced by the British Geological Survey for The Scottish Government Publications. © Crown Copyright 2007.
Retrieved from http://www.scotland.gov.uk/Publications/2007/06/04121253/1 on 11/22/07.

Hinrichsen, D., Robey, B., and Upadhyay, U.D. 1998. Solutions for a Water-Short World. Population Reports, Series M, Vol. 14. no. 1. Baltimore, Johns Hopkins School of Public Health, Population Information Program, December 1997. Retrieved from http://www.infoforhealth.org/pr/m14/m14chap2_2.shtml 11/12/07.

Kennedy, William Quarrier. 1939. The Great Glen fault [Scotland]. Geological Society of London, Abstracts with Programs, vol. 1354, pp. 42-48.

Kennedy, Willaim Quarrier. 1946. The Great Glen Fault. Quarterly Journal of the Geological Society; v. 102; issue.1-4; p. 41-76.

Lovejoy, P. and editorial staff. 2007. Mine of the Month—Glensanda: King of Quarries. April 2007 Mining Magazine, p. 17-19.
Retrieved from http://www.mining-journal.com/mines_month/pdf/glensanda.pdf on 11/14/07.

Marston, R. J. 1967. Newer Granites of Foyers and Strontian and the Great Glen Fault. Nature, 214, p.159 – 161.

Owen, T.R. 1976. The Geological Evolution of the British Isles. Pergamon Press, Oxford. 167 pp.

Rallen, RM. 2004. Simplified map of selected geologic markers of offset on the San Andreas fault. Retrieved 12/01/08 from
http://seismo.berkeley.edu/~rallen/teaching/S04_SanAndreas/Resources/OffsetMarkersHandout.pdf

Sabine, Peter A. 1963. The Strontian granite complex, Argyllshire. Bulletin of the Geological Survey of Great Britain, vol.20, pp.6-42,

Sims, J.D. 1993. Chronology on the San Andreas fault in central California: Evidence from reversed positions of exotic rock bodies near Parkfield, California. In Powell, R.E., Weldon, R.J., II, and Matti, J.C. eds., The San Andreas Fault System: Displacement, Palinspastic Reconstruction, and Geologic Evolution. Boulder, Colorado. Geological Society of America Memoir 178. p. 221-256.

Stratton, Michael; Trinder, Barrie Stuart; Trinder, Barrie. 2000. Twentieth Century Industrial Archaeology. Taylor & Francis, pg. 14. Retreived from http://books.google.com/books on 11/12/07.

ATTACH PRINT VIEW HERE