

2019 Dynamic Planet – Glaciers
Regional Science Olympiad

DIVISION ** C ** QUESTION SET

**** Please turn off your mobile devices (including phones). ****

**** Do not open the test until told to do so. ****

Team Member(s)/Student(s):

School:

Team Number (if you know it... if not, leave this blank): _____

Instructions:

- 1.) Each team may bring **two** stand-alone, non-programmable, non-graphing calculators. Calculators on mobile devices, including phones, are **not** allowed.
- 2.) Each team may bring **four** 8.5" x 11" sheets of paper that may contain information on both sides in any form and from any source.
- 3.) Time limit = **50 minutes**
- 4.) **Write your final answers on the separate answer sheet.** Only answers on the separate answer sheet will be scored.
- 5.) Use the question booklet for scratch paper if you need it.
- 6.) Turn in **all** materials (questions, answer sheets, figures) when you finish.
- 7.) Complete sentences are not required, but write clearly so we can read your answers!

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QUESTIONS 1-2: Use Figure 1.

#1 (1 pt): Fig. 1 shows that scientific research is advancing how scientists view and understand one of the ice age periods in Earth's history. Which ice age period is the focus of Fig. 1?

- A. Neoproterozoic snowball Earth ice age
- B. Late Paleozoic ice age
- C. ice age at the Eocene-Oligocene transition
- D. Pleistocene glaciation and ice age

#2 (1 pt): Scientists now consider the historic ice age that occurred during the time period shown in Fig. 1 to _____.

- A. be one, long, massive ice age that covered a large portion of the continent of Gondwana
- B. be dynamic and change with geographic location and time
- C. not affect the area that would eventually be South America
- D. not significantly affect ocean levels across this time period

QUESTIONS 3-5: No separate figures from the figure packet are needed.

#3 (1 pt): During the Pleistocene glaciation, _____.

- A. the oceans were mostly covered in sea ice
- B. the ocean levels were at their lowest in the measurable past
- C. the water cycle was virtually non-existent

#4 (1 pt): Compared to the Pliocene Epoch, the Pleistocene climate was _____.

- A. very similar
- B. warmer
- C. colder

#5 (1 pt): Which of the following is **not** a Milankovitch Cycle?

- A. eccentricity
- B. retrograde motion
- C. obliquity
- D. precession

QUESTIONS 6-8: Use Figure 2.

#6 (1 pt): Which Milankovitch cycle is shown in Fig. 2-1?

- A. eccentricity
- B. retrograde motion
- C. obliquity
- D. precession

#7 (1 pt): Which Milankovitch cycle is shown in Fig. 2-2?

- A. eccentricity
- B. retrograde motion
- C. obliquity
- D. precession

#8 (1 pt): Which Milankovitch cycle is shown in Fig. 2-3?

- A. eccentricity
- B. retrograde motion
- C. obliquity
- D. precession

QUESTIONS 9-13: Use Figures 3-5.

#9 (1 pt): Which type of frozen water is shown in Fig. 3?

- A. snow
- B. firn
- C. glacial ice

#10 (1 pt): Which type of frozen water is shown in Fig. 4?

- A. snow
- B. firn
- C. glacial ice

#11 (1 pt): Which type of frozen water is shown in Fig. 5, specifically where the black arrow is pointing?

- A. snow
- B. firn
- C. glacial ice

Imagine you are a scientist studying the frozen water shown in Fig. 4. You make a site visit to do field work and to collect data. The work is fun but challenging, and you get thirsty. You chip some of the frozen water shown in Fig. 4 off and put it in your water bottle to cool your water while you are out there working as a scientist.

#12 (1 pt): The frozen water (shown in Fig. 4) that you chipped off and placed in your drink will melt _____ than ice that you would get from your freezer at home.

- A. faster
- B. slower
- C. at the same rate as

#13 (1 pt): Why did you choose that answer in Question #12 above? The frozen water shown in Fig. 4 _____ ice cubes you would get from your freezer at home.

- A. is much COLDER than
- B. is much WARMER than
- C. has larger ice crystals than
- D. has smaller ice crystals than
- E. is totally the same as

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QUESTIONS 14-15: No separate figures from the figure packet are needed.

#14 (1 pt): If you start at the top/surface of a column of frozen water in an ice sheet, and drill down into the frozen water, the density of frozen water changes most rapidly in the _____ transition zone.

- A. snow → firn
- B. firn → snow
- C. glacial ice → firn
- D. firn → glacial ice

#15 (3 pts): In the blank graph on your answer sheet, draw a curve that shows how density of frozen water changes with depth as you go down into a glacier or ice sheet.

** Note that the axes in the blank graph on the answer sheet are already labeled for you. The y-axis is depth, with units of meters (m). The x-axis is density, in units of kilograms per cubic meter (kg/m^3).

QUESTIONS 16-20: No figures from the separate figure packet are necessary.

#16 (2 pts): Lake Vostok in Antarctica is one example of a subglacial lake. Give a short (15 words or less) definition of *subglacial lake*.

#17 (1 pt): A moulin is a nearly _____ channel in ice that is formed by _____ water.

- A. horizontal; flowing
- B. horizontal; still
- C. vertical; flowing
- D. vertical; still

#18 (4 pts): Draw a diagram to show how surface water could become subglacial water through a moulin. In your drawing:

- label surface water and draw an arrow pointing to it
- label a moulin and draw an arrow pointing to it
- label subglacial water and draw an arrow pointing to it
- include an arrow showing the direction of water movement

#19 (1 pt): Glacial outburst floods were first described in Iceland. What are these floods called?

#20 (1 pt): What is the main cause of glacial outburst floods in Iceland?

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QUESTIONS 21 - 24: Use Figure 6.

#21 (1 pt): What type of sedimentary sequence is shown in Fig. 6?

#22 (1 pt): Is the sedimentary sequence shown in Fig. 6 a **terrestrial** or **marine** deposit?

#23 (1 pt): In what type of water body did the sedimentary sequence shown in Fig. 6 form?

- A. river
- B. lake
- C. ocean
- D. estuary

#24 (6 pts): Describe how the two types of layers in the sedimentary sequence shown in Fig. 6 are formed. In your description, include an explanation of

- how the time of year/seasons play a role in the formation of these sediment layers
- the size of the grains in the two different sediment layers

QUESTIONS 25 - 27: Use Figure 7.

#25 (1 pt): What is the rock in the middle of Fig. 7 called?

#26 (1 pt): Is the rock and sedimentary sequence shown in Fig. 7 a **terrestrial** or **marine** deposit?

#27 (3 pts): Describe how the sedimentary sequence shown in Fig. 7 formed.

QUESTIONS 28-35: Use Figure 8, the SumDum (D-4), Alaska map.

#28 (2 pts): What is the name for the glacial landforms that are indicated by streaks of brown dots in the middle of the glacier (for example, see Location A in Fig. 8)?

#29 (3 pts): How did the glacial landforms like the example at Location A in Fig. 8 form?

#30 (1 pt): In what direction does the glacier flow at Location B in Fig. 8?

#31 (1 pt): What type of sediment would you most likely find at Location C in Fig. 8, **till** or **outwash**?

#32 (2 pts): How can you tell the type of sediment you named in Question #31 is likely present at Location C?

#33 (1 pt): Was Tracy Arm (see Location D in Fig. 8) carved by **rivers** or **glaciers**?

#34 (2 pts): How can you tell what carved Tracy Arm?

#35 (1 pt): What is the glacial (geomorphic) term for Tracy Arm?

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QUESTIONS 36-42: Use Figure 9, the Whitewater, WI map.

Locate the ridge outlined in black with the words "KETTLE MORaine STATE FOREST" written on it. This ridge is composed of large boulders mixed with clay.

#36 (1 pt): How would you classify the sorting of the grains in this ridge, **poorly-** or **well-** sorted?

#37 (1 pt): What was the probable mode of transport of grains to this ridge?

#38 (2 pts): What is the name/term for the glacial feature represented by this ridge?

#39 (1 pt): Is this ridge elongated **PARALLEL TO** or **PERPENDICULAR TO** the direction in which the ice advanced?

#40 (2 pts): Ice, in the area of this ridge, most likely moved in a direction from ____ to ____ .

#41 (1 pt): What is the term for the lakes such as Pleasant Lake and Blue Spring Lake (red circle in Fig. 9)?

#42 (1 pt): Put the statements that are listed below in order to explain how lakes like Pleasant Lake and Blue Spring Lake formed. List the letters in order on the separate answer sheet.

- A. Ice melted, leaving a depression.
- B. Chunks of glacial ice were left behind by retreating glacier.
- C. Ice was buried in sediment (partially or completely).

QUESTIONS 43-46: Use Figures 10-12, focused on the Matterhorn Peak area of California.

#43 (1 pt): What is the name/term for the glacial feature that is Matterhorn Peak shown in Figs. 10 (overall area, zoomed-out) and 11 (zoomed-in)?

#44 (1 pt): What is the name/term for the glacial feature that is Soldier Lake shown in Figs. 10 (overall area, zoomed-out) and 12 (zoomed-in)?

#45 (2 pts): Twin Lakes (shown in Fig. 10) are moraine-dammed lakes. Briefly explain how they formed.

#46 (1 pt): Was the area shown in Figs. 10-12 impacted by **alpine** or **continental** glaciation?

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QUESTIONS 47-50: Use Figure 13, the Sodus, NY map.

#47 (1 pt): What are the many elongated hills on this map called?

#48 (1 pt): What material are the hills composed of?

- A. till B. outwash C. bedrock

#49 (1 pt): In which direction (N, E, S, W) did the ice flow?

#50 (1 pt): Was this area impacted by **alpine** or **continental** glaciation?

QUESTIONS 51-54: Use Figure 14, the Blue Ridge, Michigan map.

The ridge (outlined in red in Fig. 14) that runs from the NE to SW across this map runs parallel to the direction that the glacier flowed.

#51 (1 pt): What is the name/term for this glacial feature?

#52 (1 pt): Explain how the ridge formed by putting the statements below in order. List the letters of the statements in order on the separate answer sheet.

- A. stream flowed on (carved a valley into) glacier
- B. sediment was let down on land to create a ridge
- C. stream left sand and gravel in its bed
- D. ice melted

#53 (1 pt): What material is the ridge most likely composed of?

- A. till B. outwash C. bedrock

#54 (1 pt): Was this area impacted by **alpine** or **continental** glaciation?

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QUESTIONS 55-58: Use Figure 15, the map of glacial features in the Midwest.

Note that glacial features correspond to certain colors as shown below. Also see legend for the map in Fig. 15.

- Eskers are shown in orange
- End Moraines in dark green
- Ground Moraine and other "drift" in light green and peach
- Outwash in yellow
- Lake Sediments in blue
- Areas not glaciated in gray

#55 (1 pt): Two end moraines are labeled in Fig. 15. Which end moraine is youngest, **A** or **B**?

#56 (3 pts): Explain why and support your answer to Question #55.

#57 (1 pt): The present day Great Lakes of Lake Huron and Lake Erie are shown in white/very light yellow in Fig. 15. Were these lakes **bigger** or **smaller** during the last Ice Age?

#58 (1 pt): Where would you find more hills than flat areas, in the **gray** area or the area shown in the **peach** color? Why?

- The gray area would be more hilly because it was glaciated.
- The gray area would be flatter because it was not glaciated.
- The peach area would be flatter because it was not glaciated.
- The peach area would be flatter because glacial sediment filled in low areas.

QUESTIONS 59-61: Use Figure 16.

#59 (1 pt): From the present day, going back to about 250,000 years ago, a rise in $\delta^{18}\text{O}$ indicates that climates were [**warming** or **cooling**].

#60 (2 pts): What is insolation?

#61 (1 pt): Is there a connection between insolation and climate, **yes** or **no**? And why?

- yes, as insolation increases, climate warms.
- yes, as insolation decreases, climate warms.
- no, there is no connection or relationship.

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QUESTIONS 62-63: Use Figure 17.

#62 (1 pt): Was sea level higher or lower at the peak of the last glacial maximum, according to Fig. 17?

#63 (1 pt): Why did you choose your answer in Question #62?

- A. Glacial meltwater added more water to the oceans.
- B. Massive evaporation over the oceans occurred, allowing more water to be stored in the atmosphere.
- C. More water was frozen and stored in the ice sheets and glacial ice.

QUESTIONS 64-67: Use Figures 18-19.

#64 (1 pt): Where was the ice sheet thickest according to Fig. 18? (Choose from the letters A-D on the map.)

#65 (1 pt): According to Fig. 19, where is the crust rising most? (Choose from the letters A-D on the map.)

#66 (1 pt): Is there a correlation between ice sheet thickness and uplift of the crust, **yes** or **no**?

#67 (2 pts): Why or why not - explain your answer to Question #66.

QUESTIONS 68-69: Use Figures 20-21.

#68 (1 pt): Which is **not** a change to the drainage system shown in Figs. 20-21 that took place as a result of the Ice Age?

- A. In preglacial times, there were no Great Lakes, and after, the Great Lakes formed.
- B. The Upper Missouri River flows into the Lower Mississippi as a result of the Ice Age, instead of flowing towards the north.
- C. The Ohio River starts further to the east today vs. in preglacial times.
- D. The glaciers and ice sheets during the Ice Age formed the Mississippi River. The Mississippi River did not exist before the Ice Age, in preglacial times.

#69 (1 pt): TRUE or FALSE: To form the Great Lakes, ice carved rivers valleys in the Great Lakes region deeper, allowing them to trap water and become lakes.

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QUESTIONS 70-72: Use Fig. 22 in the separate figure packet.

#70 (1 pt): In Fig. 22, what do the orange and red colors indicate, such as those at location 4?

- A. open water B. sea ice C. icebergs D. volcanic eruptions and lava

#71 (1 pt): In Fig. 22, what does the light blue color at locations 1, 2, and 3 indicate?

- A. open water B. clouds C. icebergs or ice shelf D. glacier

#72 (1 pt): The sensor on the Landsat satellite that captured the image in Fig. 22 is a _____ type of sensor.

- A. X-ray B. gamma-ray C. visible light D. thermal

QUESTIONS 73-74: Use Figures 23 and 24 in the separate figure packet.

NASA launched the ICESat-2 satellite on a Delta II Rocket, on September 15, 2018 from Vandenberg Air Force Base in California (see Fig. 23). The instrument aboard the ICESat-2 satellite (Fig. 24) is the Advanced Topographic Laser Altimeter System (ATLAS). What can be more exciting than space lasers to measure characteristics of ice?!?! :D

#73 (1 pt): The ATLAS instrument uses lasers to measure the elevation of the Earth's surface and whatever it contains, including ice sheets, glaciers, sea ice, forest structures, elevation of bare land, and more.

Describe how the ATLAS Laser Altimeter works by putting the statements below in the correct order. On your answer sheet, write the letters in the correct order according to the correct order of the statements.

- A. A telescope within the ATLAS instrument collects the photons and times their arrival.
- B. ATLAS shoots a laser down to earth.
- C. The laser photons bounce back towards the ICESat-2 satellite.
- D. The laser photons hit Earth's surface.
- E. The elevation or height of Earth's surface is determined by using the altitude of the ICESat-2 satellite and the time it takes for the photons to return to the collector telescope within the ATLAS instrument on ICESat-2.

#74 (1 pt): The _____ the time it takes for the laser photons emitted from the ATLAS instrument to hit Earth's surface and come back to the ICESat-2 satellite, the _____ the elevation of whatever the laser photons hit.

- A. longer; higher
- B. shorter; higher
- C. shorter; more negative (below sea level)
- D. longer; more mountainous

QUESTIONS 75-77: Use Figure 25 in the separate figure packet.

The upper part of Fig. 25 shows a satellite image of a portion of Antarctica and its nearby coast. The blue line in the upper part of Fig. 25 is a transect line. The lower part of Fig. 25 shows the elevation of Earth's surface along that transect line. The elevation data shown in the lower part of Fig. 25 came from the ICESat-2 satellite.

#75 (1 pt): In Figure 25, which location(s) indicate(s) a spot where there is seawater beneath the ice's surface? **Choose any/all that apply from the choices of 1, 2, 3, and/or 4.**

#76 (1 pt): In Figure 25, which location(s) indicate(s) a rocky shoal in the ocean that is causing higher elevation of the ice surface? **Choose any/all that apply from the choices of 1, 2, 3, and/or 4.**

#77 (1 pt): In Figure 25, which location(s) indicate(s) a continental land mass that is causing higher elevation of the ice surface? **Choose any/all that apply from the choices of 1, 2, 3, and/or 4.**

QUESTIONS 78-80: Use Figure 26 in the separate figure packet.

#78 (1 pt): What glacial feature is shown in Fig. 26, marked by alternating bands of light and dark ice?

- A. striations
- B. ogives
- C. fossilization
- D. sedimentation

#79 (1 pt): The presence of the features shown in Fig. 26, means that ice flows _____ through the center of a glacier, compared to the sides of the glacier.

- A. slower
- B. faster
- C. at the same rate

#80 (1 pt): The features like those shown in Fig. 26 typically form below _____ .

- A. crevasses
- B. mountains
- C. icefalls
- D. a glacier's terminus

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QUESTIONS 81-87: No separate figures from the figure packet are needed.

#81 (1 pt): Glacial retreat over the past 50 years can be tied to warming temperatures that are caused by ____ .

- A. thermal expansion of Earth's atmosphere
- B. Milankovitch cycles
- C. ice harvesting
- D. increases in greenhouse gases

#82 (1 pt): Glacial isostatic adjustment impacts Earth's _____ .

- A. lithosphere
- B. gravitational field
- C. oceans
- D. all of the above

#83 (1 pt): In glacial isostatic adjustment, the weight of glaciers and ice sheets _____ the Earth's lithosphere directly below the glaciers and/or ice sheets.

- A. depresses
- B. leads to elevation rises in
- C. has no impact on

#84 (1 pt): In glacial isostatic adjustment, the area surrounding ice sheets _____.

- A. sinks
- B. rises
- C. does not change

#85 (1 pt): As ice sheets _____ in response to climate change, forebulges typically begin to _____ .

- A. grow; rise
- B. grow; sink
- C. melt; rise
- D. melt; sink

#86 (1 pt): As glacial isostatic adjustment continues in modern times, will earthquakes become **more** or **less** active?

#87 (1 pt): Why did you choose the answer you chose for Question #86?

- A. Pressure on Earth's lithosphere increases as glaciers melt, suppressing earthquakes.
- B. Pressure on Earth's lithosphere decreases as glaciers melt, suppressing earthquakes.
- C. Pressure on Earth's lithosphere increases as glaciers melt, which can reactivate old faults.
- D. Pressure on Earth's lithosphere decreases as glaciers melt, which can reactivate old faults.