2019 Dynamic Planet – Glaciers
Regional Science Olympiad

DIVISION ** B ** 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!

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

QUESTIONS 1-2: Use Figure 1.

The axial tilt of the Earth changes over time. We are currently in the mid-range of tilt.

#1 (1 pt): Which of the following would NOT be a reason that the shallow tilt of the Earth's axis could lead to growing ice sheets?

A. The Sun's solar radiation is less evenly distributed between winter and summer causing extreme cold and snowfall for winter weather.

B. Winters are warmer, the warm air would be able to hold more moisture, and then produce a greater amount of snowfall.

C. Summer temperatures would be cooler, resulting in less melting of the winter's snow accumulation.

D. The smaller tilt increases the difference in radiation receipts between the equatorial and polar regions, which allows ice sheets to grow more rapidly.

#2 (1 pt): In Fig. 1, which value of axial tilt shown would lead to more extreme seasons, **24.5** or **21.5**?

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 9-15: 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

#14 (1 pt): Rank the frozen water shown in Figs. 3-5 in terms of how old the frozen water is, from *youngest* to *oldest,* by writing the figure numbers in order.

#15 (1 pt): As the frozen water examples get older, the density of the frozen water ____ .

A. stays the same in time
B. increases in time
C. decreases in time

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?

QUESTIONS 21 - 25: 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 (1 pt): The thinner, darker-colored layers in Fig. 6 were deposited in:

A. spring
B. summer
C. fall
D. winter

#25 (1 pt): The thicker, lighter-colored layers in Fig. 6 have _____ grains, compared to the thinner, darker-colored layers.

A. coarser B. finer C. the same size

QUESTIONS 26 - 28: Use Figure 7.

#26 (1 pt): What is the rock in the middle of Fig. 7 called?

#27 (1 pt): Is the rock and sedimentary sequence shown in Fig. 7 a **terrestrial** or **marine** deposit?

#28 (3 pts): Describe how the sedimentary sequence shown in Fig. 7 formed.

QUESTIONS 29-34: Use Figure 8, the SumDum (D-4), Alaska map.

#29 (1 pt): What are 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)?

A. They are lateral moraines composed of sediment on the glacier.
B. They are medial moraines composed of till on the glacier.
C. They are arêtes composed of bedrock sticking up through the glacier.
D. They are stream deposits on the glacier.

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

A. north to south
B. south to north
C. east to west
D. west to east

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

#32 (1 pt): How can you tell the type of sediment you named in Question #31 is likely present at Location C?

A. The dots on the map are all the same size.
B. The dots on the map are different sizes.

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

#34 (1 pt): What is the glacial (geomorphic) term for Tracy Arm?

A. moraine-dammed lake
B. tarn
C. kettle
D. fjord

<u>QUESTIONS 35-40</u>: 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.

<u>#35 (1 pt):</u> How would you classify the sorting of the grains?

A. poorly-sorted
B. well-sorted

<u>#36 (1 pt):</u> What was the probable mode of transport of grains to this ridge?

A. ice
B. wind
C. water

<u>#37 (2 pts):</u> What is the name/term for the glacial feature represented by this ridge?

A. esker
B. arête
C. end moraine

<u>#38 (1 pt):</u> Is this ridge elongated **PARALLEL** TO or **PERPENDICULAR** TO the direction in which the ice advanced?

<u>#39 (1 pt):</u> Ice, in the area of this ridge, most likely moved in a direction from ___ to ____ .

A. northeast to southwest
B. southwest to northeast
C. northwest to southeast
D. east to west

<u>#40 (1 pt):</u> What is the term for the many lakes such as Pleasant Lake and Blue Spring Lake (circled in red in Fig. 9)?

A. They are tarn that were carved out of solid rock by the glacier.

B. They are moraine-dammed lakes that formed when end moraines blocked stream drainage.

C. They are kettles formed when ice left from the retreating glacier was buried (partially or completely) by glacial outwash. After the ice melted it left a depression.

D. They are kettles formed when ice leftover from the retreating glacier melted leaving a pool of water.

QUESTIONS 41-44: Use Figures 10-12, focused on the Matterhorn Peak area of California.

#41 (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)?

A. drumlin B. kame C. horn D.arete

#42 (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)?

A. kettle B. tarn C. fjord D. moraine-dammed lake

#43 (1 pt): Twin Lakes (shown in Fig. 10) are _____ .

A. kettles B. tarns C. fjords D. moraine-dammed lakes

#44 (1 pt): Was the area shown in Figs. 10-12 impacted by **alpine** or **continental** glaciation?

QUESTIONS 45-48: Use Figure 13, the Sodus, NY map.

#45 (1 pt): What are the many elongated hills on this map called?

A. drumlins B. aretes C.eskers

#46 (1 pt): What material are the hills composed of?

A. till B. outwash C. bedrock

#47 (1 pt): In which direction did the ice flow?

A. northeast to southwest
B. southwest to northeast
C. northwest to southeast
D. east to west

#48 (1 pt): Was this area impacted by **alpine** or **continental** glaciation?

<u>QUESTIONS 49-54</u>: 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.

<u>#49 (1 pt):</u> What is the name/term for this glacial feature?

A. end moraine
B. kame
C. esker
D. arete

<u>#50 (1 pt):</u> What material is the ridge most likely composed of?

A. till
B. outwash
C. bedrock

<u>#51 (1 pt):</u> Was this area impacted by **alpine** or **continental** glaciation?

QUESTIONS 52-54: 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

#52 (1 pt): Two end moraines are labeled in Fig. 15. Which end moraine is youngest, **A** or **B**?

#53 (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? How can you tell?

A. smaller - there is almost no lake sediment on the map, so lakes were probably almost nonexistent during the Ice Age
B. smaller - isostatic rebound during the Ice Age led to fewer lakes
C. bigger - the large area of lake sediment (in blue), surrounding the present day lakes (in white) indicates that the lakes were bigger during the Ice Age
D. bigger - the lakes were drained through eskers (orange on the map)

#54 (1 pt): Where would you find more hills than flat areas, in the **gray** area or the area shown in the **peach** color?

A. gray, which WAS glaciated, with glaciers carving many deep valleys between hills
B. gray, which was was NOT glaciated, so glacial sediment did not fill in the low areas
C. peach, which WAS glaciated, with glaciers carving many deep valleys between hills
D. peach, which was NOT glaciated, so glacial sediment did not reach the peach-colored areas

QUESTIONS 55-57: Use Figure 16.

#55 (1 pt): From the present day, going back to about 250,000 years ago, a rise in $\delta^{18}O$ indicates that climates were [**warming** or **cooling**].

#56 (1 pt): What is insolation?

A. source of heat at Earth's center
B. a way to make something less likely to change temperature
C. incoming solar radiation
D. outgoing longwave radiation

#57 (1 pt): Is there a connection between insolation and climate?

A. No
B. Yes, and when insolation increases, the climate warms.
C. Yes, and when insolation decreases, the climate cools.

QUESTIONS 58-59: Use Figure 17.

#58 (1 pt): Was sea level higher or lower at the peak of the last glacial maximum, according to Fig. 17?

#59 (1 pt): Why did you choose your answer in Question #58?

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 60-62: Use Figures 18-19.

#60 (1 pt): Where was the ice sheet thickest according to Fig. 18? (Choose from the letters A-D on the map.)

#61 (1 pt): According to Fig. 19, where is the crust rising most? (Choose from the letters A-D on the map.)

#62 (1 pt): Is there a correlation between ice sheet thickness and uplift of the crust?

A. No, where the ice sheet was thickest, the uplift today is the least
B. No, where the ice sheet was thickest, the uplift today is the most
C. Yes, where the ice sheet was thickest, the uplift today is the least
D. Yes, where the ice sheet was thickest, the uplift today is the most

QUESTION 63: Use Figures 20-21.

#63 (1 pt): Compare Figs. 20 and 21. How did the Great Lakes form?

A. Catastrophic floods during the Laurentide Ice Sheet's melting widened existing river valleys to create the lake basins.

B. The ice sheet carved out existing river valleys even further to create lake basins.

C. High sea levels during the last glacial maximum allowed seawater to reach the midwestern United States, creating estuaries and also lakes.

D. Isostatic rebound, after the ice sheet melted, completely dammed up river outlets and allowed the lakes to form.

QUESTIONS 64-66: Use Fig. 22 in the separate figure packet.

#64 (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

#65 (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

#66 (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 67-68: 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

#67 (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.

#68 (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 69-71: 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.

#69 (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.**

#70 (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.**

#71 (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 72-74: Use Figure 26 in the separate figure packet.

#72 (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

#73 (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

#74 (1 pt): The features like those shown in Fig. 26 typically form below _____ .

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