Answer Key

Answers to Study Questions

1. *Glacier* is a term that refers to an accumulation of ice on land that lasts for a significant amount of time and is capable of moving downhill under gravitational pull. Glaciers can form wherever the amount of snow received exceeds the amount of snow lost. Alpine glaciers form in mountainous terrain, whereas continental glaciers occur where glacial ice covers a significant portion of the continent.

2. The glacier ice on Antarctica, which constitutes about 85% of all present day glacier ice, is the world's largest resource of freshwater.

3. A *valley glacier* is a body of ice that occurs within the confines of a valley and migrates downhill under the pull of gravity. *Ice sheets*, on the other hand, are not confined to valleys and comprise bodies of ice in excess of 50,000 km^2. Bodies of ice that are smaller than 50,000 km^2 are referred to as *ice caps*.

4. Snow that consists of snowflakes with air trapped in between them is called *powder snow*. Most freshly fallen snow is powder snow. With time, however, weight from overlying snow compacts powder snow, squeezing the air out. This reduces snowflakes to granules, and in warmer climates, thawing and refreezing processes produce granules that are very coarse. These granules are called *corn snow*.

5. With continued snow falls, granular snow becomes compacted and forms a consistency that is intermediate between snow and glacier ice. This material is called *firn*. As snow continues to accumulate, firn gets buried deeper, and more air is driven out. This reduces the pore spaces in the firn significantly, and the grains of ice assume an interlocked structure that characterizes glacier ice.

6. Calving occurs when moving glaciers reach a body of water, and segments of the ice break off the glacier to float away as icebergs.

7. An advancing glacier is one that has a positive budget, or a net increase in accumulating snow. Hence, an advancing glacier expands in size as its margins extend outwards. When a glacier loses more water (through melting or otherwise) than it gains as snow, it has a negative budget, and will shrink in size or form a receding glacier. A glacier that is losing as much water as it is gaining as snow has a balanced budget: it will neither advance nor retreat.

8. The zone of accumulation is found in the upper part of a glacier. Here, the snow cover is permanent. The zone of ablation, on the other hand, occurs in the lower part of the glacier. In the zone of ablation, snow is lost through melting, calving, or evaporation. The equilibrium line occurs somewhere between the zone of accumulation and the zone of ablation. The equilibrium line demarcates the highest point up the glacier where winter snow is lost during the melt season.

9. The main force driving glacial movement is gravity.

10. Ice movement within a valley glacier is fastest in the central part of the glacier, whereas ice moves slower at the sides because of friction. Movement also decreases towards the base of the glacier where ice moves through basal sliding.

11. Within the plastic zone, the ice grain on the upper part slides farther than the underlying grain. In the rigid zone, on the other hand, the ice grains are locked together and move in unison. Hence, within the rigid zone, the distance moved by grains in the lower part of the zone is similar to that moved by grains in the upper part of the zone (they move together).

12. The rate of movement on a glacier is not uniform. In places where the valley bottom drops, for instance, the ice moves faster. However, because ice is a rigid material, it does not flow in response to the greater rate of movement. Instead, cracks develop on the ice to accommodate the movement and crevasses form as a result. The same effect occurs on curves when parts of the glacier move faster than others. Similarly, in curves, crevasses develop in response to tensional stress.

13. Ice movement in ice sheets generally moves from a central high out to the lower areas. However, this movement is not uniform. Rather, the movement is concentrated in ice streams, which are sections of the ice that move faster than the rest. As a result of this movement, the ice surface of ice streams is characteristically intensely crevassed. Hence, boundaries of an ice stream can be delineated by identifying heavily crevassed zones.

14. *Rock flour* describes sediment comprising silt and clay-sized particles that is produced by the grinding of rock against rock during glacial transport. Glaciers often carry large rocks (up to the size of large boulders), and as these are dragged on hard bedrock, they form rock flour.

15. Rocks that are collected by the glacier in the zone of accumulation are integrated into the glacier itself and transported within it. Material that accumulates in the zone of ablation collects on the surface of the glacier, and is transported on top of it.

16. Glacially-carved valleys are characterized by U-shaped cross profiles. Stream carved valleys are typically V-shaped.

17. As glaciers erode bedrock, the sections that are more resistant to erosion stand out as protuberances on the valley floor after the glacier is gone. Occasionally, such protrusions may be elongated and parallel to the direction of glacial flow. These are called *roches moutonnées*.

18. Cirques are basin-shaped structures that form at the head of a valley largely due to the erosional action of a glacier, but also due to weathering of rock above the ice through processes such as frost wedging.

19. *Till* is a general term used to describe loose sediment of widely ranging sizes that is transported and deposited by a glacier. Till is not sorted and lacks layering.

20. An *erratic* is a huge boulder transported by a glacier and deposited in terrain with bedrock different from that which it was derived.

21. *Moraine* is till that is transported and deposited by a glacier. *Lateral moraine* is till deposited along the sides of a valley glacier. Where two glacial valleys meet, lateral moraines can be sandwiched by ice to result in a linear body of moraine in the centre of the glacier, which is called *medial moraine*. *End moraine* develops when the leading edge of the glacier remains stationary for some time, such that till accumulates to form a ridge in front of it.

22. The terminal moraine (or end moraine) demarcates the farthest point reached by a glacier. A recessional moraine, on the other hand, is an end moraine built while the end point of a receding glacier was temporarily stationary.

23. *Drumlins* are mounds of till that are deposited by a glacier in the direction of ice movement. Drumlins usually possess a streamlined form, and are believed to develop under glaciers.

24. *Outwash* refers to material deposited by meltwater released by a glacier in the zone of ablation. Outwash is well sorted, and is layered similar to fluvial sediments. Because of this layering, outwash deposits can easily be distinguished from till. An *esker* is a type of outwash landform characterized by winding mounds of sediment deposited by the water released by retreating glaciers.

25. As ice sheets retreat from formerly glaciated terrain, isolated blocks of ice sometimes remain behind, and these are subsequently surrounded and buried by sediment. When these blocks of ice eventually melt, they leave behind depressions called *kettles*.

26. The term *varve* refers to a depositional sequence representing fine-grained lake sediment emplaced in a single year. Varves often occur in pairs of depositional layers, one lighter in colour, representing sediment deposited during the warmer part of the year, and another, darker in colour, representing sediment deposited during the cooler period.

27. The primary cause for glacial ages is believed to be variations in the amount of solar energy reaching the earth. The changes result from variations in the angle at which the sun's rays reach the earth as well as the distance between the earth and the sun as the Earth revolves around the sun. These variations occur with cycles of 21,000, 41,000, and 100,000 years (Milankovitch cycles), and they are the primary causes of glacial and interglacial cycles.
    Geological records show that these cycles have been predominant during the Pleistocene era (approximately the last 2.5 million years). However, since Milankovitch cycles are believed to have existed before that, there must be reasons why ice ages were relatively less frequent prior to the Pleistocene era. Researchers have proposed that changes in the composition of the atmosphere, the position of continents, and in circulation of sea water are all possible causes for the increase in ice age frequency.

28. The Great Lakes were produced when ice sheets that extended into southern Canada and the northern United States widened fluvial valleys by erosion. When the glaciers retreated, they left behind deep and wide landforms that were subsequently filled by water to form huge lakes.

29. Lake Agassiz was a huge lake that formed on the southern edge of the retreating Laurentide ice sheet southeast of what is now the Hudson Bay. To the north, the retreating ice sheet acted as a dam, such that water could not drain north to the sea. At the same time, the melting ice sheet provided water for the lake, so the lake grew as the ice sheet shrank.

30. Pluvial lakes are lakes that developed in some regions of the world during glacial periods as climates in those areas became more humid.

31. The water that formed ice sheets and glaciers during glacial periods came primarily from precipitation that had evaporated from the sea. Hence, as the ice sheets increased in size, less water was finding its way back to the sea after precipitation. As a result, the sea level dropped appreciably during glacial periods.

32. The presence of thick sequences of ice on the Earth's surface places significant stress on the Earth's crust. In response to that load, the Earth's crust may deform isostatically to accommodate the stress. However, once the ice melts and the stress is removed, the Earth's crust will rebound to its original form. These adjustments, manifested

in the gradual vertical movements of the Earth's crust, can take up to thousands of years to complete.