PRACTICING TO TAKE THE

GRE® GEOLOGY TEST

2nd Edition

INCLUDES:

- An actual GRE Geology Test administered in 1991-92
- Sample questions, instructions, and answer sheets
- Percentages of examinees answering each question correctly

AN OFFICIAL PUBLICATION OF THE GRE BOARD

ETS Published by Educational Testing Service
for the Graduate Record Examinations Board

The Graduate Record Examinations Program offers a General Test measuring developed verbal, quantitative, and analytical abilities and Subject Tests measuring achievement in the following 16 fields:

Biochemistry, Cell and Molecular Biology	Economics	Literature in English	Political Science
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The Graduate Record Examinations Board has officially made available for purchase practice books, each containing a full-length test, for 15 of the Subject Tests. A practice book is not available for the Biochemistry, Cell and Molecular Biology Test at this time. Two General Test practice books are also available.

Individual booklets describing each test and including sample questions are available free of charge for all 16 Subject Tests. You may request these booklets by writing to:

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USA: 0-446-39471-8
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BACKGROUND FOR THE TEST

PRACTICING TO TAKE THE GRE® GEOLOGY TEST

This practice book has been published on behalf of the Graduate Record Examinations Board to help potential graduate students prepare to take the GRE Geology Test. The book contains the actual GRE Geology Test administered in October 1991, along with a section of sample questions, and includes information about the purpose of the GRE Subject Tests, a detailed description of the content specifications for the GRE Geology Test, and a description of the procedures for developing the test. All test questions that were scored have been included in the practice test.

The sample questions included in this practice book are organized by content category and represent the types of questions included in the test. The purpose of these questions is to provide some indication of the range of topics covered in the test as well as to provide some additional questions for practice purposes. These questions do not represent either the length of the actual test or the proportion of actual test questions within each of the content categories.

Before you take the full-length test, you may want to answer the sample questions. A suggested time limit is provided to give you a rough idea of how much time you would have to complete the sample questions if you were answering them on an actual timed test. After answering the sample questions, evaluate your performance within content categories to determine whether you would benefit by reviewing certain courses.

This practice book contains a complete test book, including the general instructions printed on the back cover. When you take the test at the test center, you will be given time to read these instructions. They show you how to mark your answer sheet properly and give you advice about guessing.

Try to take this practice test under conditions that simulate those in an actual test administration. Use the answer sheets provided on pages 127 to 132 and mark your answers with a No. 2 (soft-lead) pencil as you will do at the test center. Give yourself 2 hours and 50 minutes in a quiet place and work through the test without interruption, focusing your attention on the questions with the same concentration you would use in taking the test to earn a score. Since you will not be permitted to use them at the test center, do not use keyboards, dictionaries or other books, compasses, pamphlets, protractors, highlighter pens, rulers, slide rules, calculators (including watch calculators), stereos or radios with headphones, watch alarms including those with flashing lights or alarm sounds, or paper of any kind.

After you complete the practice test, use the work sheet and conversion tables on pages 67 and 68 to score your test. The work sheet also shows the estimated percent of GRE Geology Test examinees from a recent three-year period who

answered each question correctly. This will enable you to compare your performance on the questions with theirs. Evaluating your performance on the actual test questions as well as the sample questions should help you determine whether you would benefit further by reviewing certain courses before taking the test at the test center.

We believe that if you use this practice book as we have suggested, you will be able to approach the testing experience with increased confidence.

ADDITIONAL INFORMATION

If you have any questions about any of the information in this book, please write to:

Graduate Record Examinations
Educational Testing Service
P.O. Box 6000
Princeton, NJ 08541-6000

PURPOSE OF THE GRE SUBJECT TESTS

The GRE Subject Tests are designed to help graduate school admission committees and fellowship sponsors assess the qualifications of applicants in their subject fields. The tests also provide students with an assessment of their own qualifications.

Scores on the tests are intended to indicate students' knowledge of the subject matter emphasized in many undergraduate programs as preparation for graduate study. Since past achievement is usually a good indicator of future performance, the scores are helpful in predicting students' success in graduate study. Because the tests are standardized, the test scores permit comparison of students from different institutions with different undergraduate programs.

The Graduate Record Examinations Board recommends that scores on the Subject Tests be considered in conjunction with other relevant information about applicants. Because numerous factors influence success in graduate school, reliance on a single measure to predict success is not advisable. Other indicators of competence typically include undergraduate transcripts showing courses taken and grades earned, letters of recommendation, and GRE General Test scores.

DEVELOPMENT OF THE GRE GEOLOGY TEST

Each new edition of the Geology Test is developed by a committee of examiners composed of professors in the subject who are on undergraduate and graduate faculties in different types of institutions and in different regions of the United States. In selecting members for the committee of examiners, the GRE Program seeks the advice of the National Association of Geology Teachers.

The content and scope of each test are specified and reviewed periodically by the committee of examiners who, along with other faculty members who are also subject-matter specialists, write the test questions. All questions proposed for the test are reviewed by the committee and revised as necessary. The accepted questions are assembled into a test in accordance with the content specifications developed by the committee of examiners to ensure adequate coverage of the various aspects of the field and at the same time to prevent overemphasis on any single topic. The entire test is then reviewed and approved by the committee.

Subject-matter and measurement specialists on the ETS staff assist the committee of examiners, providing information and advice about methods of test construction and helping to prepare the questions and assemble the test. In addition, they review every test question to identify and eliminate language, symbols, or content considered to be potentially offensive, inappropriate, or serving to perpetuate any negative attitudes. The test as a whole is also reviewed to make sure that the test questions, where applicable, include an appropriate balance of people in different groups and different roles.

Because of the diversity of undergraduate curricula in geology, it is not possible for a single test to cover all the material an examinee may have studied.

The examiners, therefore, select questions that test the basic knowledge and understanding most important for successful graduate study in the field. The committee keeps the test up-to-date by regularly developing new editions and revising existing editions. In this way, the test content changes steadily but gradually, much like most curricula.

When a new edition is introduced into the program, it is equated; that is, the scores are related by statistical methods to scores on previous editions so that scores from all editions in use are directly comparable. Although they do not contain the same questions, all editions of the Geology Test are constructed according to equivalent specifications for content and level of difficulty, and all measure equivalent knowledge and skills.

After a new edition of the Geology Test is first administered, examinees' responses to each test question are analyzed to determine whether the question functioned as expected. This analysis may reveal that a question is ambiguous, requires knowledge beyond the scope of the test, or is inappropriate for the group or a particular subgroup of examinees taking the test. Such questions are not counted in computing examinees' scores.

CONTENT OF THE GRE GEOLOGY TEST

The test consists of about 195 multiple-choice questions, some of which are grouped in sets and based on such materials as diagrams, maps, and graphs.

Modern geological thinking crosses many subject boundaries, and numerous questions reflect this tendency. Nevertheless, each question reasonably falls into one of the three major categories listed below. A separate subscore is reported for each of these three categories; there are approximately the same number of questions in each of the three categories. The approximate percentages of questions on each topic in recent test editions are shown on the next page.

Topic	Percentage of Questions
I. STRATIGRAPHY, SEDIMENTOLOGY, PALEONTOLOGY, GEOMORPHOLOGY, AND HYDROLOGY	33
A. Stratigraphy	7
B. Sedimentology	9
C. Paleontology (invertebrate and vertebrate)	8
D. Geomorphology	4
E. Hydrology	3
F. General, including oceanography	2
II. STRUCTURAL GEOLOGY AND GEOPHYSICS	33
A. Structure — field relations	8
B. Structure — dynamics (experimental and theoretical)	7
C. Tectonics	5
D. Isostasy, gravity, and magnetism	4
E. Earthquakes and seismology	4
F. Heat and electrical properties	3
G. General, including planetology	2
III. MINERALOGY, PETROLOGY, AND GEOCHEMISTRY	33
A. Mineralogy (chemical composition, physical properties, and crystallography)	9
B. Petrology, including field relations	11
C. Geochemistry	7
D. Isotope geology	3
E. Economic mineral deposits and resources	3

The questions are also designed to measure important abilities, as follows:

- Ability to analyze geologic phenomena using, for example, maps, graphs, cross sections, block diagrams, diagrams resulting from instrumental methods, and perceptions in three dimensions
- Ability to comprehend geological processes, including comprehension through the application of physics, chemistry, biology, and mathematics
- Ability to demonstrate knowledge of basic geology

For students who did not major in geology as undergraduates but plan to enter geology at the graduate level, the GRE Subject Tests in the areas of their undergraduate majors would be more appropriate for them to take than the GRE Geology Test.

SAMPLE QUESTIONS

The sample questions included in this practice book represent the types of questions included in the test. The sample questions are in two groups: questions 1-159 are organized by content category and questions 160-173 cover a range of topics and have been grouped together because they represent a different question type. The purpose of the sample questions is to provide some indication of the range of topics covered in the test as well as to provide some additional questions for practice purposes. These questions do not represent either the length of the actual test or the proportion of actual test questions within each of the content categories. A time limit of 150 minutes is suggested to give you a rough idea of how much time you would have to complete the sample questions if you were answering them on an actual timed test. Correct answers to the sample questions are listed on page 63.

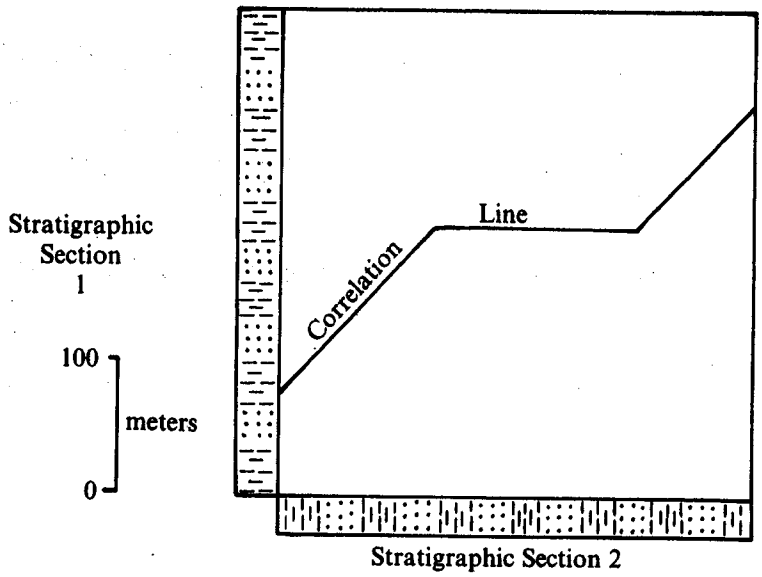
Directions: Each of the questions or incomplete statements is followed by five suggested answers or completions. Select the one that is best in each case.

I. STRATIGRAPHY, SEDIMENTOLOGY, PALEONTOLOGY, GEOMORPHOLOGY, AND HYDROLOGY

A. STRATIGRAPHY (Questions 1-4)

1. Some Archean rocks were melted deep within the Earth's crust during the Ordovician Period. In the Silurian Period the magma thus produced cooled and crystallized into a granite batholith. In the Permian Period this batholith was exposed at the Earth's surface and detritus eroded from it was transported to a nearby sedimentary basin, deposited, and lithified into sandstone. In the Cretaceous Period this sandstone was folded into steeply-dipping beds and in the Pliocene these were eroded into hogbacks where the sandstone may be studied today. The age of the sandstone is

   (A) Archean
   (B) Silurian
   (C) Permian
   (D) Cretaceous
   (E) Pliocene



2. The correlation line above was constructed from many points that represent bases and tops of range zones of fossil species common to sections 1 and 2, which are 100 kilometers apart. Which of the following best describes the history the line represents?

   (A) In section 2 deposition began earlier, slowed more markedly for awhile in the middle part, and then ended earlier than in section 1.
   (B) Deposition began and ended earlier in section 1 than in 2, but sedimentation was markedly much more rapid in the middle part of 2 than of 1.
   (C) Deposition began earlier and continued later in section 2 than in section 1, but the middle part of 2 contains an unconformity.
   (D) Deposition began earlier and continued later in section 1 than in section 2, but the middle part of 1 contains an unconformity.
   (E) Deposition began earlier and continued later in section 2 than in section 1 and the middle part of 1 contains an unconformity.

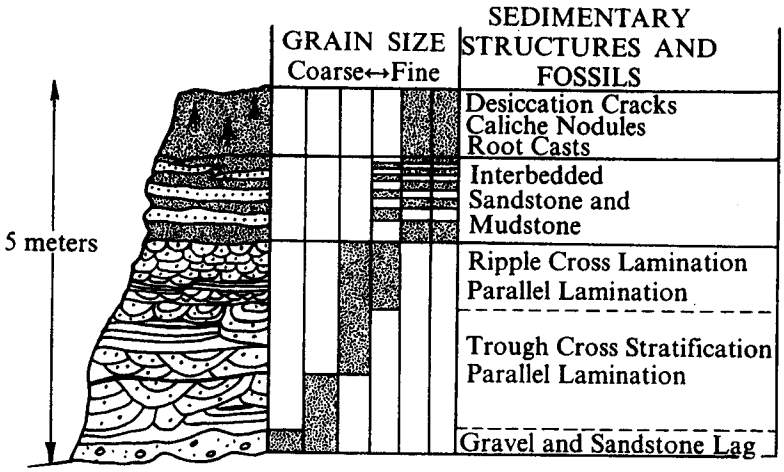
3. Which of the following groups of criteria is most critical in defining a formation?

   (A) A rock body that is characterized by lithologic homogeneity and can be mapped on a scale of the order of 1:20,000
   (B) A rock body that is characterized by lithologic homogeneity and has the exact same age throughout
   (C) A rock body with traceable upper and lower boundaries and a recognizable fossil assemblage
   (D) A rock body with distinctive color and a thickness of at least 10 m
   (E) A biostratigraphic unit characterized by faunal homogeneity but not necessarily the same age throughout

4. From east to west across an almost continuous exposure of a single regionally extensive sedimentary formation, the same index fossil appears successively higher above the basal contact of the unit. Which of the following explanations best accounts for this relationship?

   (A) The rate of evolution was slow.
   (B) Erosion and redeposition of fossils as detritus occurred.
   (C) The formation is time-transgressive.
   (D) The fossils constitute a facies fossil; i.e., sensitive to environment.
   (E) The plate motion at the time of deposition was westward.

B. SEDIMENTOLOGY (Questions 5-17)



5. The sequence of strata above is repeated several times in a stratigraphic succession. The probable depositional environment is a

   (A) small delta
   (B) tidal flat
   (C) shoreface-to-lagoon transition
   (D) meandering stream
   (E) sabka

6. Of the following, the best way to distinguish a point bar deposit of a river from the deposit of a meandering tidal channel is by the

(A) thickness of the deposits
(B) vertical sequence of bedding types
(C) mineral content
(D) age of the deposits
(E) differences in grain size

7. The steepness (slope) of the central portion of a cumulative curve representing the size distribution of a sediment is a rough approximation of

(A) average grain shape
(B) average grain size
(C) skewness
(D) sphericity
(E) degree of sorting

8. A first-generation sandstone consisting almost entirely of rounded quartz grains indicates

(A) physical disintegration of a granite source rock nearby
(B) the reconstitution of the original clay into quartz
(C) its origin as a chemical precipitate
(D) the removal of nonquartz minerals by decomposition or abrasion
(E) a diagenetic accumulation of quartz grains

9. All of the following processes may occur during diagenesis EXCEPT the

(A) transmission of pore fluids
(B) alteration of biotite
(C) cementation of sand
(D) development of varves
(E) growth of analcime in claystone

10. Which of the following fossils is a floating form that leaves pencil-like saw-toothed marks in black shales?

(A) Ammonite
(B) Fusuline
(C) Graptolite
(D) Crinoid
(E) Bryozoan

11. A typical vertical sequence of sediment through a point bar would show

(A) interstratified sand and shale
(B) thick homogeneous sand
(C) an upward gradation from sand to shale
(D) an upward gradation from shale to sand
(E) thick laminated shale

12. Evaporation of sea water gives rise in succession to

(A) $CaCO_3$, $CaSO_4 \cdot 2H_2O$, KCl, NaCl
(B) $CaCO_3$, $CaSO_4 \cdot 2H_2O$, NaCl, KCl
(C) $CaCO_3$, NaCl, $CaSO_4 \cdot 2H_2O$, KCl
(D) NaCl, $CaSO_4 \cdot 2H_2O$, $CaCO_3$, KCl
(E) NaCl, $CaSO_4 \cdot 2H_2O$, KCl, $MgCl_2$

13. Sequences that coarsen upward characterize which of the following pairs of environments?

(A) Prograding barrier island coasts. .prograding deltas
(B) Prograding barrier island coasts. .prograding tidal flats
(C) Prograding tidal flats. .turbidites
(D) Diamictites. .turbidites
(E) Prograding deltas. .sand dunes

14. Paleozoic sedimentary rock units in continental cratons typically include which of the following?

(A) An abundance of basaltic detritus
(B) Thick, elongate prisms of dark slate and graywacke
(C) Isoclinal folds
(D) Delta deposits of subgraywacke sandstone, claystone, and shale
(E) Thin, widespread sheets of well-sorted quartz and calcite sand

15. In a sedimentary column, which of the following is the principal effect of the conversion of beds of anhydrite to gypsum?

(A) Volume increase
(B) Volume decrease
(C) Release of calcium
(D) Release of sulfate
(E) Precipitation of sulfides

16. Which of the following combinations of beds is developed under the hydraulic conditions of the lower flow regime?

(A) Antidunes, current ripples, and ripples superimposed on dunes
(B) Dunes, current ripples, and ripples superimposed on dunes
(C) Dunes, antidunes, chutes, and pools
(D) Plane beds, antidunes, chutes, and pools
(E) Plane beds, antidunes, and current ripples

17. Which of the following does NOT normally occur during compaction of sandstone at a depth of 4,000 meters?

(A) Expulsion of pore water
(B) Pressure solution of quartz at grain-to-grain contacts
(C) Bending of flexible mica grains
(D) Shifting of grains into tighter packing patterns
(E) Fracturing of quartz and feldspar grains

C. PALEONTOLOGY (Questions 18-32)

18. Which of the following sequences represents the generally accepted order of evolution of the vertebrates?

(A) Fishes → Amphibians → Reptiles ↗ Birds / ↘ Mammals

(B) Mammals → Reptiles ↗ Amphibians / ↘ Fishes → Birds

(C) Amphibians → Fishes → Reptiles ↗ Birds / ↘ Mammals

(D) Reptiles ↗ Amphibians → Mammals / ↘ Fishes → Birds

(E) Birds → Mammals → Fishes → Reptiles → Amphibians

19. Which of the following characteristics is NOT suitable for an index fossil?

(A) Narrow environmental tolerance
(B) Rapid evolution
(C) Great abundance
(D) Distinctive morphology
(E) Well-known ancestry

20. The greatest single evolutionary advance the reptiles made over the amphibians was

(A) external ears
(B) eggs with shells
(C) body temperature regulation
(D) stronger tail muscles
(E) differentiated teeth

21. Which of the following environments best characterizes the natural habitat of boring bivalves, green algae, herbivorous snails, and filter feeding cirriped crustaceans?

(A) Deltaic interdistributary pond
(B) Bathyal marine
(C) Rocky intertidal coast
(D) Hypersaline lagoon
(E) Outer neritic mud bottom

22. Fossils of marine planktic organisms are generally superior to those of marine benthic organisms for worldwide correlation primarily because planktic organisms

(A) are produced in greater numbers
(B) are deposited in more varied environments
(C) evolve more rapidly
(D) migrate more rapidly
(E) live in a wider range of environmental conditions

23. Of the following, the most useful group of guide fossils for the Upper Paleozoic is

(A) corals
(B) fusulinids
(C) bryozoans
(D) trilobites
(E) coccolithophorids

24. Which of the following fossil groups is most useful in the paleobathymetrical analysis of subsurface data?

(A) Ammonoidea
(B) Radiolaria
(C) Planktic foraminifera
(D) Benthic foraminifera
(E) Graptolites

25. Which of the following groups is the most useful for intercontinental correlations of Mesozoic rocks?

(A) Echinoids
(B) Pelecypods
(C) Sponges
(D) Ammonoid cephalopods
(E) Nautiloid cephalopods

26. In which of the following are the groups listed in order of their appearance in the geologic record?

(A) Metazoans, procaryotic organisms, eucaryotic organisms, shell-making organisms
(B) Metazoans, eucaryotic organisms, shell-making organisms, procaryotic organisms
(C) Procaryotic organisms, eucaryotic organisms, shell-making organisms, metazoans
(D) Procaryotic organisms, eucaryotic organisms, metazoans, shell-making organisms
(E) Shell-making organisms, metazoans, eucaryotic organisms, procaryotic organisms

27. Which of the following conditions is the most critical to the formation of a bioclastic limestone?

(A) A fully tropical climate
(B) A lack of diluting terrigenous sediment
(C) A high rate of productivity of shell-producing organisms
(D) A low energy setting
(E) A low latitude location

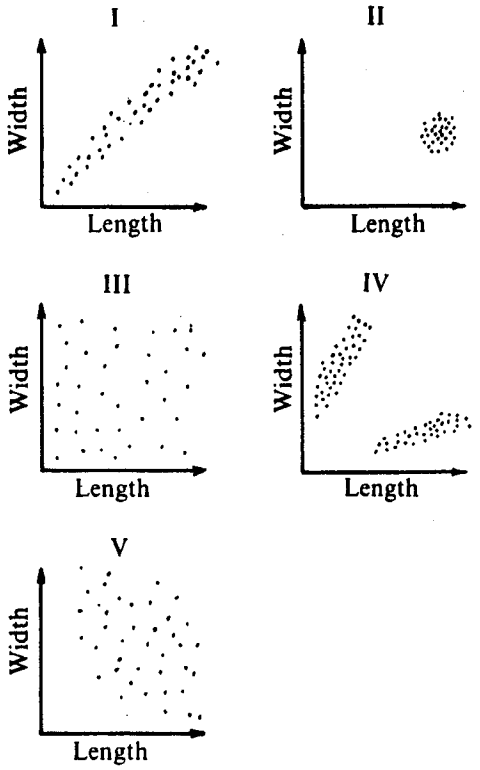
28. Graptolites, extinct animals of the Paleozoic era, were probably most closely related to

(A) molluscs
(B) conodonts
(C) archaeocyathids
(D) echinoderms
(E) chordates

29. Which of the following statements about trace fossils is most accurate?

(A) Their major disadvantage is that they are commonly displaced.
(B) They are exclusively found in marine deposits.
(C) They are reliable indicators of the age of strata.
(D) They are valuable paleoecologic and paleoenvironmental tools.
(E) They are only rarely present in sandstones.

Questions 30-31 are based on graphs I-V. Each graph represents measurements of 1,000 individual fossils.



30. Which graph represents a fossil group whose length-width ratio is roughly the same for all individuals, even though a large variety of sizes occurred?

(A) I
(B) II
(C) III
(D) IV
(E) V

31. In which two graphs does each most likely represent a group composed of a single species?

(A) I and II
(B) I and IV
(C) II and III
(D) II and IV
(E) III and IV

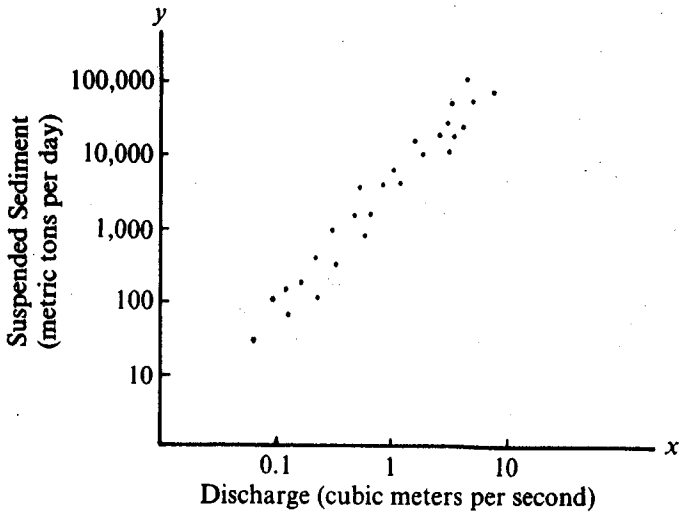
32. A black shale containing pyrite, graptolites, and a dwarf fauna was probably deposited in which of the following depositional environments?

(A) High-energy nearshore
(B) Fluvial
(C) Eolian
(D) Stagnant basin
(E) Glacial lake

D. GEOMORPHOLOGY (Questions 33-42)

33. One of the features of modern coral reefs that has led many geologists to support Darwin's theory of subsidence is the

(A) uniform depth of the lagoons in the centers of atolls
(B) well-developed sea cliffs on the islands surrounded by barrier reefs
(C) largely solutional character of the inner margins of barrier reefs
(D) great thickness of reef material underlying atolls
(E) zone of most active growth on the outer edges of most reefs



34. The graph above shows individual observations of measured suspended sediment load and water discharge for a river. From the graph, which of the following can be concluded?

(A) Both suspended sediment load and discharge are normally distributed.
(B) The relationship $y = ax$ between suspended sediment load and discharge data may be a consequence of the relationship between discharge and stream velocity.
(C) The relationship $y^a = kx^b$ might be used to estimate suspended sediment loads from discharge data.
(D) The observational scatter makes it difficult to determine the relationship between discharge and suspended sediment load.
(E) Fluctuations of suspended sediment and discharge during the period observed prevent the calculation of an average yearly value.

35. Which of the following geologic processes is LEAST likely to be found operating at the surface of the Moon?

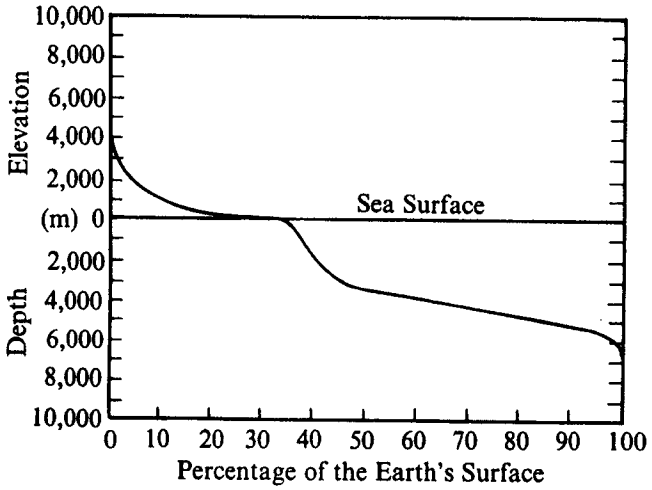
(A) Devitrification of natural glass
(B) Slumping and landsliding
(C) Sand dune formation
(D) Compaction of particulate material under pressure
(E) Radioactive decay of potassium to argon

36. In a high, mountainous region where glaciers extend down to an elevation of 2,400 meters above sea level, winds blow from the sea 800 kilometers to the west. The glaciers will recede if

(A) a high mountain range is uplifted to the west of the glaciated mountains
(B) a high mountain range is uplifted 800 km to the east of the glaciated mountains
(C) a change in climatic conditions results in the concentration of the precipitation in the winter months without changing total precipitation
(D) the average annual precipitation is increased by 25 cm without changing the distribution of the precipitation
(E) the mean annual temperature is lowered 6°C

37. In addition to weathering, the major factor in pediment development is

(A) lacustrine activity
(B) glacial action
(C) organic activity
(D) wind erosion
(E) running water



38. The two very distinct levels in the hypsometric curve shown above are caused by

(A) orogenic activity on land
(B) more rapid deposition in shallow seas
(C) historical accident
(D) loss of matter from ocean basins to the Moon
(E) density differences between continental and oceanic crust

39. Cols, arêtes, and tarns are examples of

(A) alpine glacial deposition
(B) continental glacial deposition
(C) alpine glacial erosion
(D) continental glacial erosion
(E) none of the above

40. A braided stream usually indicates that the stream

(A) has greater competency than capacity
(B) has greater load than capacity
(C) has greater capacity than load
(D) is old
(E) is at grade

41. Which of the following geomorphic features is usually characterized by measuring its length, amplitude, thalweg, sinuosity, and radius of curvature?

(A) River meander
(B) Esker
(C) Medial moraine
(D) Kame terrace
(E) Pingo

42. In the longitudinal profile of a stream, which of the following is true of a knickpoint?

(A) It must eventually move upstream and disappear.
(B) It must lie imbricated in the upstream direction.
(C) It must eventually move downstream and merge with the local base level.
(D) It must eventually move downstream and merge with sea level.
(E) It must remain fixed in position for the life of the stream.

E. HYDROLOGY

43. An artesian water well would most likely result from tapping which of the following?

(A) A bed of clay near a large lake
(B) The water table beneath the surface of the ground
(C) An underground stream in limestone
(D) An inclined water-bearing stratum underlying shale
(E) An underground flow of water beneath a dry-stream valley

F. GENERAL, INCLUDING OCEANOGRAPHY (Questions 44-46)

44. Flat-topped seamounts provide evidence for inferring that

(A) the ocean basins are comparatively young
(B) the Pacific atolls are younger than Cretaceous
(C) waves cause erosion at great depths
(D) the sea floor has subsided relative to the ocean surface
(E) volcanic cones are removed by seismic activity

45. To date no pre-Mesozoic sedimentary rocks have been found in the Pacific or Indian Ocean basins. Which of the following statements most adequately explains why this is so?

(A) Ocean basins did not exist prior to Mesozoic time.
(B) Pre-Mesozoic sedimentary rocks cannot be identified stratigraphically because they lack fossils.
(C) Pre-Mesozoic sedimentary rocks are probably widespread, but lie deeply buried beneath younger deposits.
(D) Oceanic crust of pre-Mesozoic age has been subducted or accreted during sea-floor spreading.
(E) Rates of Paleozoic sedimentation in the deep ocean basins were extremely low because of low relief of continental areas during that era.

46. Which of the following most strongly suggests that large numbers of meteorites bombarded the Earth early in its history?

(A) Meteor craters are more abundant in old rocks than in young rocks.
(B) The Moon underwent extensive meteorite bombardment early in its history and hence the nearby Earth must have undergone similar bombardment.
(C) Meteor craters have been produced experimentally under conditions thought to approximate those existing early in the Earth's history.
(D) Concentrations of high-pressure impact minerals are common in early Precambrian rocks.
(E) The meteorite flux shows that meteorite collisions are becoming less frequent with time and hence that impacts must have been more common in the ancient past.

II. STRUCTURAL GEOLOGY AND GEOPHYSICS

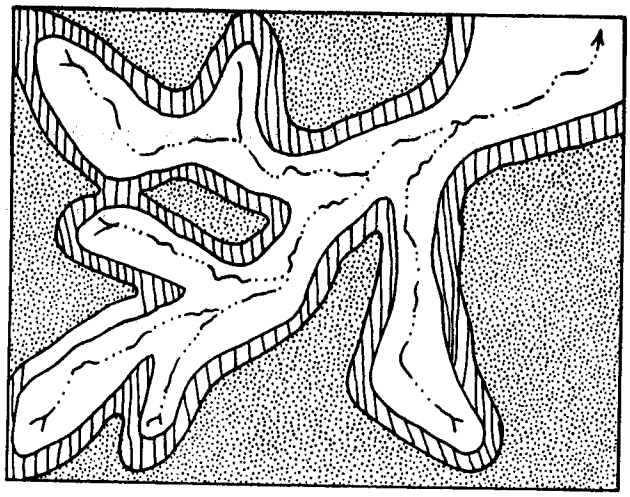
A. STRUCTURE — FIELD RELATIONS (Questions 47-65)

47. An early lineation that is refolded by a flexural slip fold whose axis is oblique to the lineation will plot on a stereonet as

(A) a great circle whose pole is the fold axis
(B) a great circle with the slip line determined by the intersection of that great circle and the axial surface of the fold
(C) a small circle whose center has no kinematic significance
(D) a small circle whose center is the fold axis
(E) an irregular line

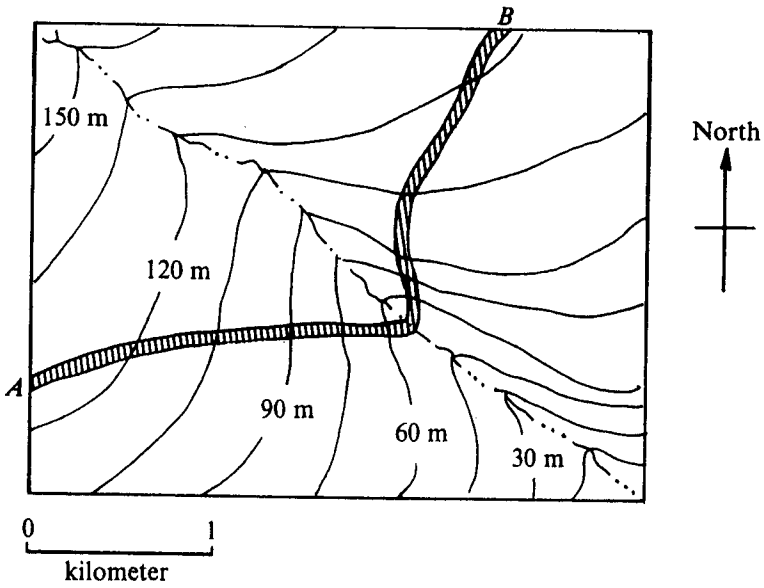
48. A metamorphic terrain consists mostly of isoclinally folded greenstone, with some intercalated metagraywacke and marble. Which of the following criteria would be most helpful in determining the top and bottom of these strata?

(A) Flute casts
(B) Abundant garnets in the upper part of the marble beds and abundant tremolite in their lower parts
(C) Load casts of metagraywacke in the upper part of the greenstone
(D) Graded bedding in the marble
(E) Pillow structures in the greenstone



49. Which of the following is the most likely geologic structure of the area shown in the map above?

(A) A complex of sharply folded anticlines plunging generally eastward
(B) A complex of sharply folded synclines plunging generally eastward
(C) A monocline dipping steeply southeastward
(D) Horizontal rock layers
(E) A refolded fold with axes trending northeast and northwest

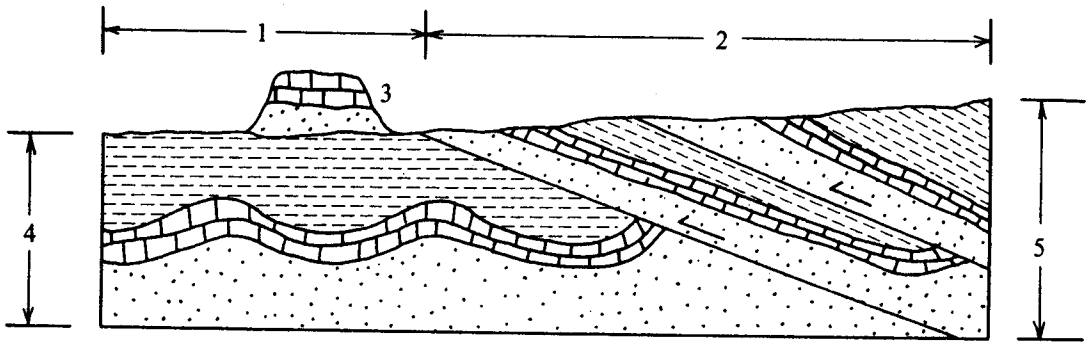


50. The topographic map above shows the line of outcrop of a relatively thin planar bed of rock *A-B*. The geologic structure of bed *A-B* is

(A) a homocline dipping northwest
(B) a homocline dipping southeast
(C) an anticlinal nose plunging southeast
(D) a synclinal nose plunging southeast
(E) indeterminate from this map

51. **Which of the following could be used to determine most accurately the net slip along a fault?**

(A) Topographic feature
(B) Sill or distinctive subhorizontal bed
(C) Dike or distinctive dipping bed
(D) Intersection of a dike and a bed
(E) Stratigraphic facies change



52. Which of the following sets of structural terms best describes the features of the diagram above?

(A) 1. Foreland
2. Klippe
3. Allochthon
4. Autochthon
5. Overthrust sheets

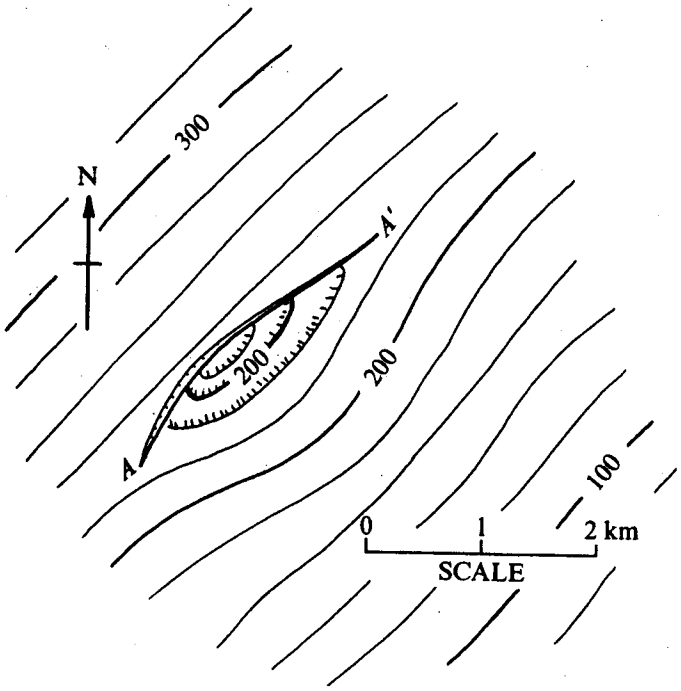
(B) 1. Klippe
2. Allochthon
3. Autochthon
4. Overthrust sheets
5. Foreland

(C) 1. Foreland
2. Overthrust sheets
3. Klippe
4. Autochthon
5. Allochthon

(D) 1. Allochthon
2. Overthrust sheets
3. Klippe
4. Foreland
5. Autochthon

(E) 1. Autochthon
2. Overthrust sheets
3. Klippe
4. Allochthon
5. Foreland

Questions 53-56 pertain to the structural map below, which shows the configuration of the top of a structural mapping unit deeply buried in a major sedimentary basin. Elevations shown are in meters above sea level.



53. As indicated by the map, what is the direction of regional dip of this unit?

(A) Southeast
(B) Southwest
(C) Northeast
(D) Northwest
(E) It cannot be determined from this map.

54. What is the direction of displacement of the fault *A-A'*?

(A) Downthrown to the northwest
(B) Downthrown to the northeast
(C) Downthrown to the southeast
(D) Downthrown to the southwest
(E) It cannot be determined from this map.

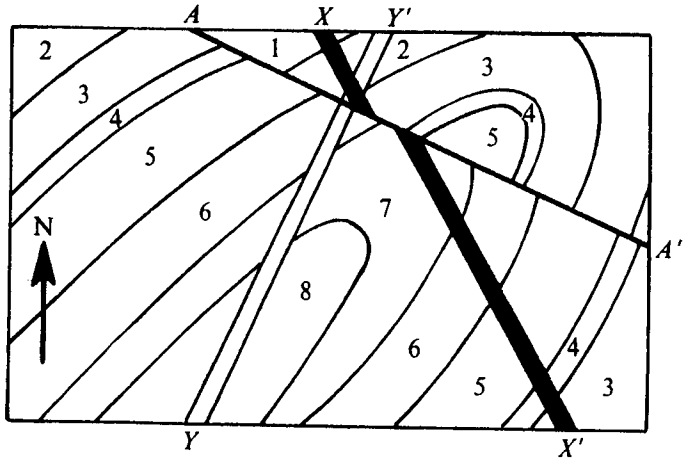
55. What is the approximate magnitude of regional dip of this unit in the mapped area, measured in meters of dip per kilometer of distance?

(A) Less than 10 m/km
(B) 20-25 m/km
(C) 40-45 m/km
(D) 80-90 m/km
(E) It cannot be determined from this map.

56. What is the maximum magnitude of the fault *A-A'* measured in meters of vertical displacement?

(A) 0-20 m
(B) 30-40 m
(C) 60-70 m
(D) 80-90 m
(E) It cannot be determined from this map.

Questions 57-59 refer to the geologic map below. The map area has essentially no topographic relief and covers approximately 5 square kilometers. Mapped units 1 to 7 are strata numbered in order of relative geologic age on the basis of well-preserved fossils (1 is oldest; 7 is youngest). Unit 8 is composed of schist, slate, and metavolcanics. *A-A'* is a fault; *X-X'* is a basalt dike; *Y-Y'* is a rhyolite dike. Prospect pits developed on mineralization along *A-A'* and *Y-Y'* show that both are vertical.



57. The major structure of the area mapped is

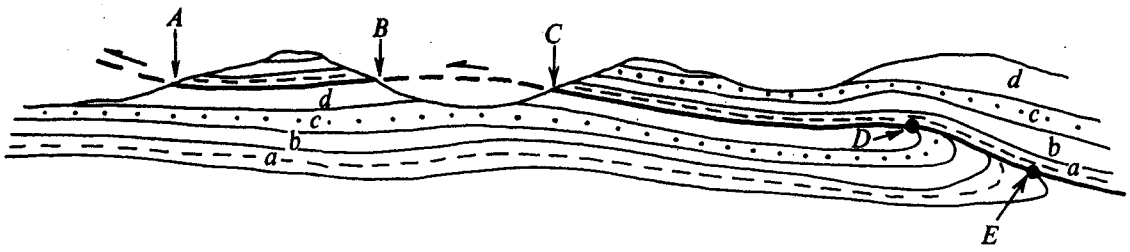
(A) an anticline plunging northeast
(B) an anticline plunging southwest
(C) a syncline plunging northeast
(D) a syncline plunging southwest
(E) a refolded anticline now a synform

58. The movement along fault *A-A'* has been

(A) lateral only, with the northern block moving southeast
(B) lateral only, with the northern block moving northwest
(C) vertical only, with the northern block moving up
(D) vertical only, with the northern block moving down
(E) both vertical and lateral, in equal amounts

59. Which of the following is true of dike *X-X'*?

(A) It was intruded along a reverse fault dipping southwest.
(B) It was intruded along a normal fault dipping northeast.
(C) It dips northeast.
(D) It is vertical.
(E) It dips southwest.

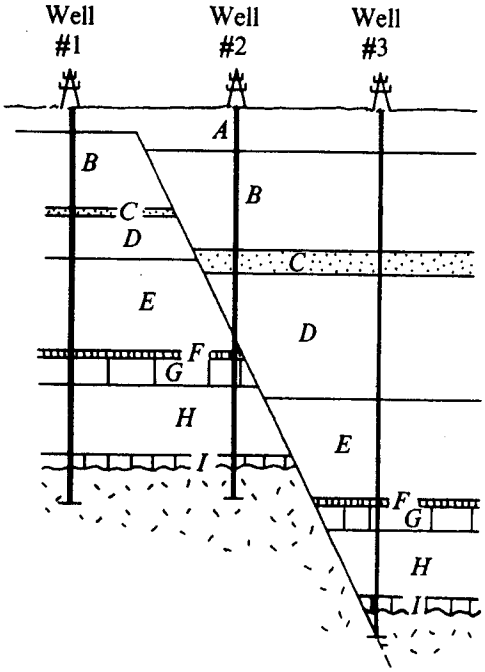


60. If one assumes that the cross section of the thrust-faulted terrain shown above is drawn parallel to the direction of net slip on the fault, the measure of net slip is

(A) *AB*
(B) *AC*
(C) *AD*
(D) *AE*
(E) indeterminable from this cross section

Questions 61-63

The structural cross section shown below is based on information from logged wells that have penetrated to basement rock.



61. The type of fault represented in the cross section above is a

(A) reverse fault
(B) normal fault
(C) thrust fault
(D) strike-slip fault
(E) transform fault

62. This cross section indicates that faulting first became active during deposition of bed

(A) *A* (B) *B* (C) *C* (D) *D* (E) *H*

63. When was the most recent period of active faulting?

(A) During deposition of bed *A*
(B) During deposition of bed *C*
(C) During deposition of bed *D*
(D) During deposition of bed *H*
(E) It cannot be determined from this cross section.

---

64. Map view separation along a fault is

(A) a measure of the actual relative displacement
(B) a reliable indicator of the dip of the fault
(C) a vector quantity reflecting the fundamental nature of the fault
(D) the amount of displacement between planes measured normal to the planes
(E) a two-dimensional view of apparent relative displacement in a single plane

65. Accumulations of hydrocarbons generally would NOT be expected to occur

(A) along synclinical axes
(B) in faulted anticlines
(C) in stratigraphic traps
(D) in Paleozoic reefs
(E) in ancient point bars

B. STRUCTURE — DYNAMICS (QUESTIONS 66-74)

66. Slaty cleavage can be useful in regional structural analysis because the planes of schistosity usually

(A) can be related to the strain ellipsoid
(B) indicate directions of crossfolding
(C) parallel bedding planes
(D) are normal to the axis of a major anticline
(E) are the youngest structures in the region

67. Which of the following stratigraphic sequences would be most conducive to the development of disharmonic folding?

(A) A continuous sequence of uniformly but thinly bedded sandstone
(B) A sequence of cherty dolomite intercalated with shale and overlaying a thick shale section
(C) A carbonate sequence alternating limestone and dolomite with thin shale partings
(D) A thickly bedded sequence of limestone, sandstone, and dolomite
(E) A well-bedded sequence of orthoquartzites with variable bed thickness

68. Strain along only two out of three perpendicular directions is termed

(A) deformation of a plane
(B) vertical strain
(C) plane strain
(D) homogeneous strain
(E) simple shear strain

69. Shear fractures formed in triaxial compression lie

(A) in the planes of maximum tangential stress
(B) at an angle greater than 45° from the least principal stress
(C) at an angle greater than 45° from the greatest principal stress
(D) parallel to the plane of the greatest and intermediate stress axes
(E) parallel to the plane of the least and intermediate stress axes

70. The fact that rocks sometimes fold without fracture indicates that under certain physical conditions they behave mechanically as

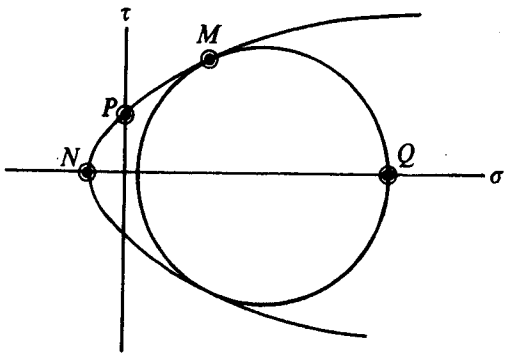
(A) elastic solids
(B) ductile solids
(C) rigid solids
(D) Kelvin solids
(E) elastic liquids

71. Large-scale, low-angle overthrusts pose a problem for which of the following reasons?

(A) Such structures are confined to the margins of eugeosynclinal belts.
(B) No comparable structures are recognized in shield areas.
(C) The heat created by friction exceeds the stability field of carbonates found in thrust sheets.
(D) As shown by the Coulomb friction model, internal friction is a variable dependent on rock parameters.
(E) The apparent stress differential in overthrust sheets exceeds the compressive strength of the rocks.

72. Translation gliding in minerals during deformation most likely occurs by

(A) simultaneous slip along boundaries between mineral grains
(B) consecutive movement of dislocations along the translation plane
(C) propagation of Griffith cracks
(D) twinning
(E) microfracturing



73. In the Mohr diagram above, the Mohr envelope of fracture is shown and a two-dimensional state of stress is plotted as a circle. What do the four points *M*, *N*, *P*, and *Q* represent?

(A) *M* = normal and tangential stress at rupture
N = cohesive strength
P = tensile strength
Q = minimum principal stress

(B) *M* = normal and tangential stress at rupture
N = minimum principal stress
P = tensile strength
Q = maximum principal stress

(C) *M* = cohesive strength
N = intrinsic fracture strength
P = tensile strength
Q = maximum principal stress

(D) *M* = normal and tangential stress at rupture
N = tensile strength
P = intrinsic fracture strength
Q = maximum principal stress

(E) *M* = normal and tangential stress at rupture
N = tensile strength
P = cohesive strength
Q = maximum principal stress

74. From deformed oolites in limestones, a geologist can determine the

(A) orientation of the finite strain ellipsoid
(B) orientation of the infinitesimal strain ellipsoid
(C) orientation of the stress ellipsoid
(D) orientation of the stress deviator
(E) strain history during multiple deformations

C. TECTONICS (Questions 75-81)

75. A Benioff zone is

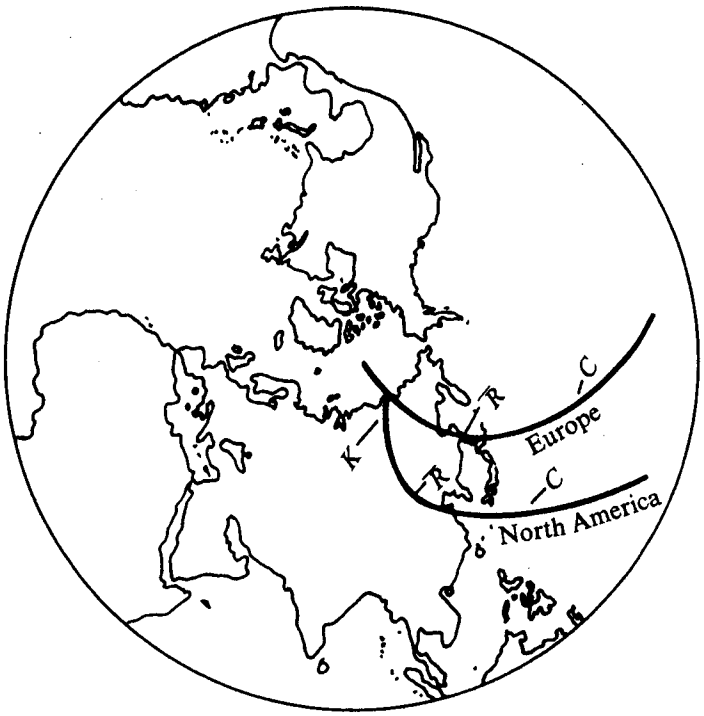
(A) a plane of structural dislocations in a crystal structure
(B) a dipping plane of earthquake foci
(C) an arid region on the leeward side of mountain ranges in low latitudes
(D) a metamorphic aureole around an igneous intrusion
(E) a depth range in the oceans characterized by great faunal abundance

76. Which of the following statements about plate tectonics is NOT true?

(A) Volcanoes are concentrated near plate boundaries.
(B) The distance between Europe and North America across the Atlantic ocean is increasing.
(C) Large-scale geologic and paleoclimatic features match when Africa and South America are reassembled.
(D) The widths of marine magnetic anomalies vary with the reversal time scale and the rate of relative plate motion.
(E) Continental edges match across the Atlantic and Pacific oceans.

77. Seismic first-motion studies have indicated that displacements on transform faults connecting segments of oceanic ridges are which of the following?

(A) Vertical, in a vertical plane perpendicular to the fault trace
(B) Vertical, in a vertical plane containing the fault trace
(C) Horizontal, in a vertical plane perpendicular to the fault trace
(D) Horizontal, in a vertical plane containing the fault trace
(E) None of the above

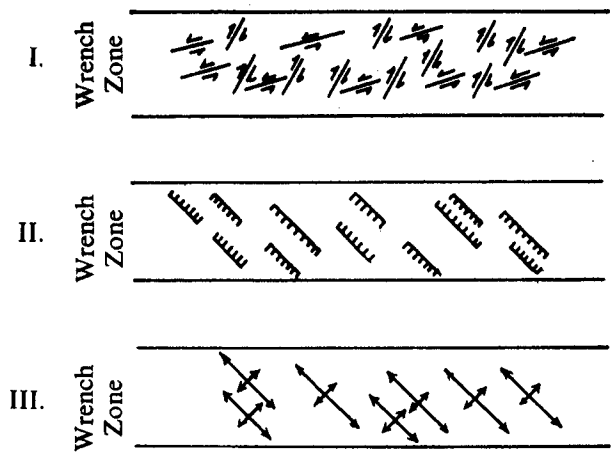


78. Separate apparent polar wandering curves like those shown in the illustration above are considered the result of

(A) a nondipolar magnetic field during the late Phanerozoic
(B) progressive separation of the continents during the late Phanerozoic
(C) reversals in the Earth's magnetic field during the late Phanerozoic
(D) lack of correspondence between the magnetic and geographic poles during the late Phanerozoic
(E) error in magnetic determinations caused by the widely varying methods employed by different workers

79. Thrust faults in many orogenic belts can be hypothesized to be most closely associated with

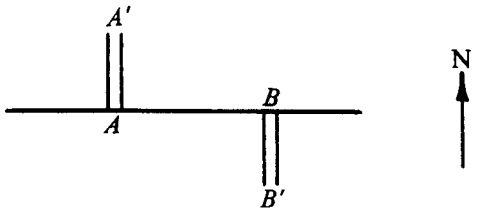
(A) regional crustal shortening
(B) regional epeirogenic uplift
(C) local diapirism
(D) solution collapse structures
(E) the emplacement of postorogenic dikes



80. The figures above show a map view of a large-scale wrench fault (strike-slip) zone, which is overlain by sedimentary rock cover. The smaller-scale structures are strike-slip fault traces in I, normal fault traces in II, and fold axial traces in III. If the wrench zone is left-lateral (counterclockwise), the structures shown in which of the figures would be expected to form during the wrenching of the cover rocks?

(A) I only
(B) II only
(C) III only
(D) I and III only
(E) I, II, and III

The map below shows two segments of an active mid-ocean ridge system joined by a vertical fault zone.



81. According to the concept of seafloor spreading, which of the following is true of displacements along the fault zone between ridge terminations at *A* and *B*?

(A) They should be predominantly of the left-lateral (sinistral) strike-slip type.
(B) They should be predominantly of the right-lateral (dextral) strike-slip type.
(C) They should be predominantly of the dip-slip type.
(D) They are indeterminable unless the actual location of the map area is known.
(E) They are indeterminable through existing seismological techniques.

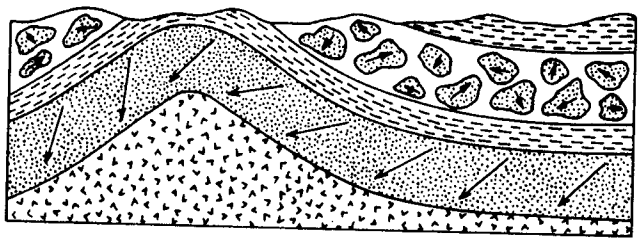
D. ISOSTASY, GRAVITY, AND MAGNETISM (Questions 82-91)

82. A negative Bouguer gravity anomaly over a mountain range is commonly interpreted as an indication that the

(A) lower and denser part of the crust is missing
(B) near-surface rocks in the mountains are less dense than normal
(C) upper mantle is denser than normal
(D) lower crust is denser than normal
(E) crustal rocks are thicker than normal below the mountains

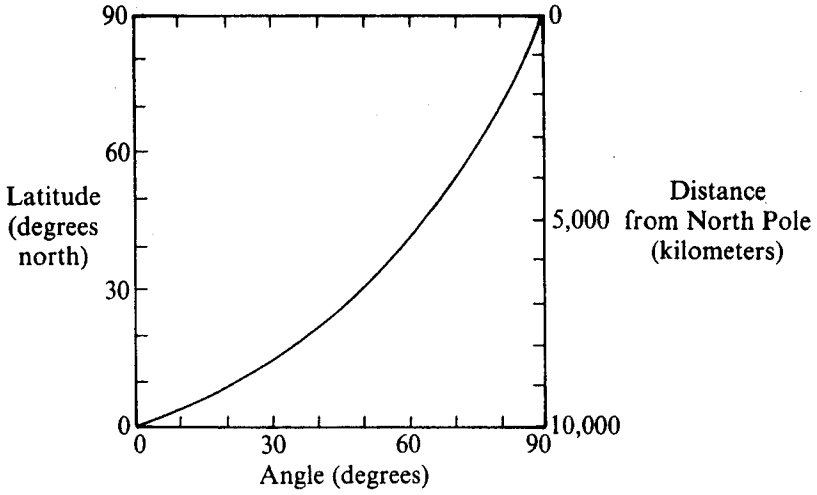
83. Why is the magnetic anomaly over an active spreading ridge larger in magnitude than older anomalies farther from the ridge crest?

(A) Oxidation of titanomagnetite by hydrothermal activity in the upper part of the oceanic crust causes a decrease in effective magnetic susceptibility.
(B) Hydration and chloritization of iron-rich olivine and pyroxene in oceanic crust causes a decrease in effective magnetic susceptibility.
(C) A shallower position of the Curie temperature away from the ridge crest causes a decrease in effective magnetic susceptibility.
(D) Heat flow decreases away from the ridge crest.
(E) During the Cenozoic the intensity of the Earth's magnetic field has been steadily increasing.



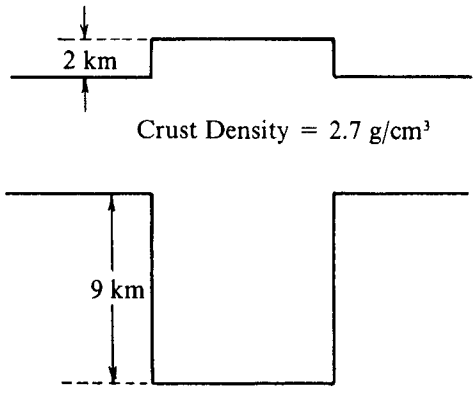
84. Directions of remanent magnetization are shown in a folded sedimentary rock and in pebbles of a conglomerate derived from it, as illustrated above. These relationships indicate that

(A) magnetization took place while the Earth's field was changing
(B) magnetic directions are unreliable in sedimentary rocks
(C) the magnetization has been affected by stress
(D) the Earth's magnetic field was unstable at the time of conglomerate deposition
(E) the magnetization is stable



85. The graph above shows the angle

(A) between the Sun's rays and the Earth's surface at the summer solstice
(B) between the geomagnetic field and the Earth's surface
(C) of impact of meteorites striking the Earth
(D) of dip of subduction zones
(E) of the first derivative of the Earth's tidal bulge



86. Assume the crustal configuration indicated in the diagram above. If the plateau, rising to a height of 2 kilometers above the surrounding terrain, is isostatically compensated, the density of the mantle is

(A) 2.2 g/cm^3
(B) 2.7 g/cm^3
(C) 3.3 g/cm^3
(D) 4.5 g/cm^3
(E) 5.4 g/cm^3

87. The best evidence for regional isostasy is provided by which of the following?

(A) Lines of volcanoes
(B) Regional metamorphism
(C) Discordance of dip
(D) Regional unconformities
(E) Regionally tilted shoreline features

88. The fundamental hypothesis of paleomagnetism states that the paleolatitude ϕ of a sample at the time it acquired its magnetism is related to the magnetic inclination I of the sample by

$$\tan I = 2 \tan \phi$$

A sample with magnetic inclination I of $+45°$ acquired its magnetism within which of the following latitude ranges?

(A) $90°$ to $60°$
(B) $60°$ to $30°$
(C) $30°$ to $-30°$
(D) $-30°$ to $-60°$
(E) $-60°$ to $-90°$

89. In a foreland basin containing 10,000 meters of sedimentary beds, the most convincing evidence that sinking was contemporaneous with deposition is that

(A) all formations thicken toward the center of the basin
(B) all formations show features and fossils characteristic only of those found in shallow water
(C) graywackes are present throughout the sequence
(D) volcanic materials are present throughout the sequence
(E) all the sediments were deposited subaerially

90. In the plate tectonic model, the outer part of the Earth is divided into a lithosphere and an asthenosphere. These two layers are

(A) contiguous at the top of the low-velocity channel within the upper mantle
(B) contiguous at the bottom of the low-velocity channel within the upper mantle
(C) contiguous at the bottom of the low-velocity channel within the crust
(D) separated by a zone of higher density rocks at the base of the crust
(E) the same as the crust and upper mantle

91. The main dipolar magnetic field of the Earth is generated by

(A) the cooling of oceanic basalts below their Curie point
(B) fluid motions in the outer core
(C) magnetohydrodynamic waves in the inner core
(D) the magnetization of the crust
(E) the magnetization of the lower mantle

E. EARTHQUAKES AND SEISMOLOGY (Questions 92-98)

92. Which of the following is the best evidence that the Earth's core acts as a fluid?

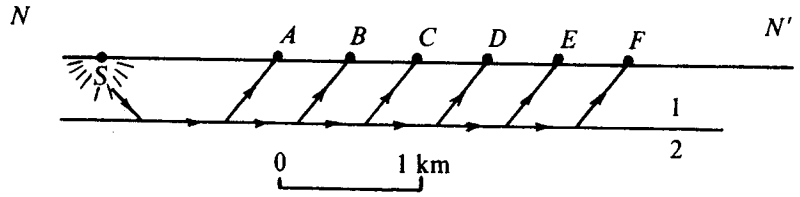
(A) *P*-wave velocities decrease at the core boundary.
(B) *S* waves are not transmitted through the core.
(C) *P* waves undergo diffraction at the core boundary.
(D) Rayleigh waves are dispersed.
(E) Waves are picked up in the "shadow zone."

93. The base of the Earth's crust is defined principally by

(A) a sharp increase in the velocity of compressional waves from about 6.8 to 8.0 km/sec
(B) the disappearance of shear waves
(C) analysis of cores from deep drilling near the continental margins
(D) heat flow measurements taken in continental interiors
(E) petrographic analysis of basic volcanic rocks from continental margins

Questions 94-95

The illustration below is a geologic section showing a simple seismic array. Layers 1 and 2 are rock beds in which the seismic *P*-wave velocities are V_1 and V_2, respectively, $V_1 < V_2$; *S* is the shot point; *A*, *B*, *C*, *D*, *E*, and *F* are geophone positions, and arrows show critical ray paths.



94. The geometry of the seismic array above indicates that the purpose of the procedure is

(A) earthquake detection
(B) seismic reflection profiling
(C) seismic refraction profiling
(D) measurement of gravity
(E) detection of magnetic anomalies

95. Which signal(s) is (are) of greatest importance in this seismic procedure?

(A) The one which follows the ground roll
(B) The first recorded arrival of each geophone
(C) All reflected events
(D) The last detectable signal
(E) All signals are of equal importance.

96. Seismic velocities in a rock are functions of the rock's

(A) elastic constants divided by density
(B) elastic constants divided by mean atomic weight
(C) grain size multiplied by density
(D) grain size multiplied by mean atomic weight
(E) density divided by porosity

97. Compressional waves from an earthquake can provide a warning of a potential seismic sea wave (tsunami) because they

(A) travel at slower speeds than shear waves
(B) travel as seismic surface waves
(C) are most sensitive to structure near their source
(D) propagate at nearly the same speed as sea waves
(E) propagate to the most distant parts of the Earth in less than 30 minutes

98. A seismic *P* wave traveling through the upper continental crust is observed to have a velocity of 6 kilometers per second and a period of 2 seconds. What is its wavelength?

(A) 1/3 km
(B) 3 km
(C) 8 km
(D) 12 km
(E) 2^6 km

F. HEAT AND ELECTRICAL PROPERTIES (Questions 99-102)

99. The electrical resistivity of sedimentary rocks depends primarily on the

(A) volume and salinity of pore water
(B) proportions of various rock-forming minerals present
(C) content of sulfide minerals
(D) content of clay
(E) temperature and pressure

100. Which of the following tectonic elements is typically associated with high present-day heat flow?

(A) Paleozoic intracratonic basin
(B) Paleozoic mobile belt
(C) Oceanic ridge
(D) Oceanic trench
(E) Precambrian craton

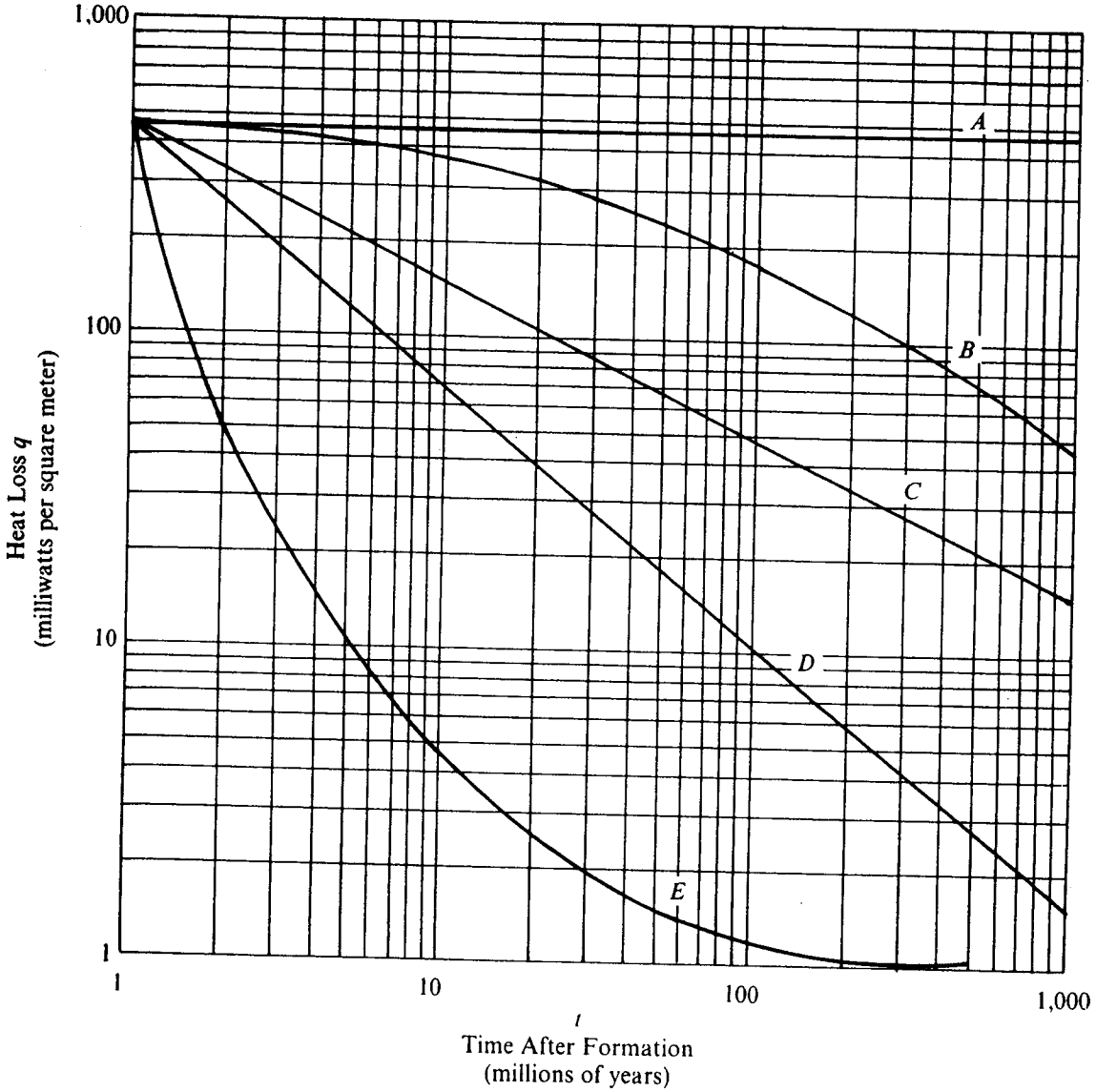
101. Temperature measurements of 35°C and 42°C were obtained in a vertical borehole at depths of 817 and 1,023 meters, respectively. What is the geothermal gradient in the borehole over this depth interval?

(A) 0.034°C per millimeter
(B) 0.34°C per centimeter
(C) 0.34°C per meter
(D) 34.0°C per 100 meters
(E) 34.0°C per kilometer

102. A typical section of oceanic lithosphere, formed by igneous processes at a mid-ocean ridge, loses heat according to the equation

$$q(t) = 473\, t^{-1/2},$$

where q is heat loss in milliwatts per square meter and t is time after formation in millions of years. Which curve on the graph below correctly depicts this relationship?



(A) *A*
(B) *B*
(C) *C*
(D) *D*
(E) *E*

G. GENERAL, INCLUDING PLANETOLOGY (Questions 103 & 104)

103. Which of the following factors is of fundamental importance in the development of salt domes?

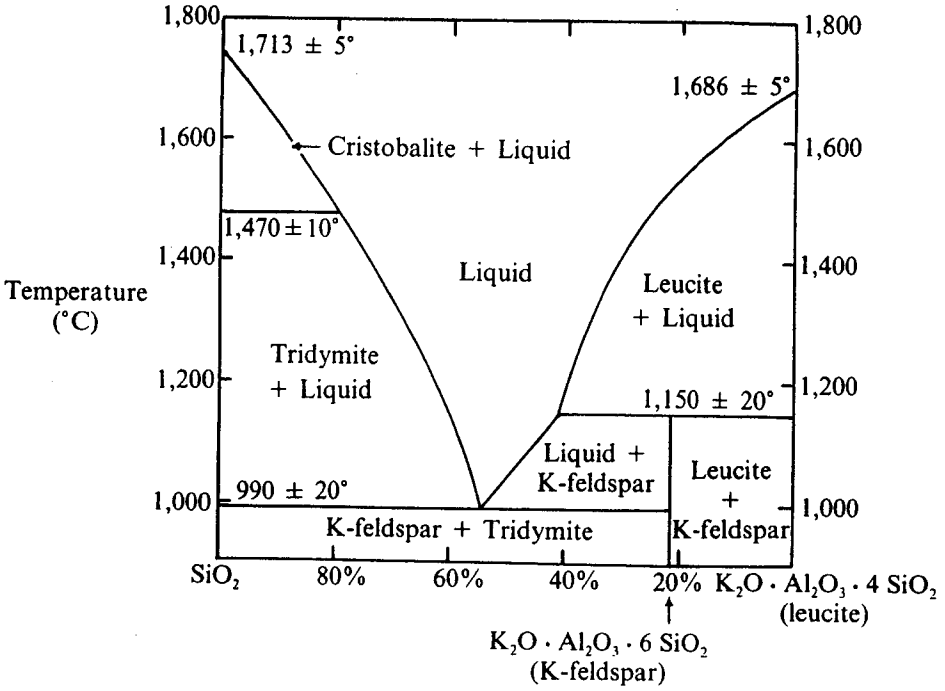
(A) Abnormal pore pressure
(B) Igneous intrusions
(C) The high water solubility of halite
(D) The low permeability of rock salt
(E) The relatively low density of rock salt

104. Which of the following statements is true of geostrophic currents that form the large oceanic gyres?

(A) They spiral inward in the Northern Hemisphere and outward in the Southern Hemisphere.
(B) They cause a depression in the sea due to centrifugal force.
(C) They circulate clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere.
(D) They are more intense in the eastern parts of oceans than in the western.
(E) They circulate around areas of high productivity.

III. MINERALOGY, PETROLOGY, AND GEOCHEMISTRY

A. MINERALOGY (Questions 105-120)



105. According to the diagram above, the solid mixture that will melt totally at the lowest temperature consists of approximately

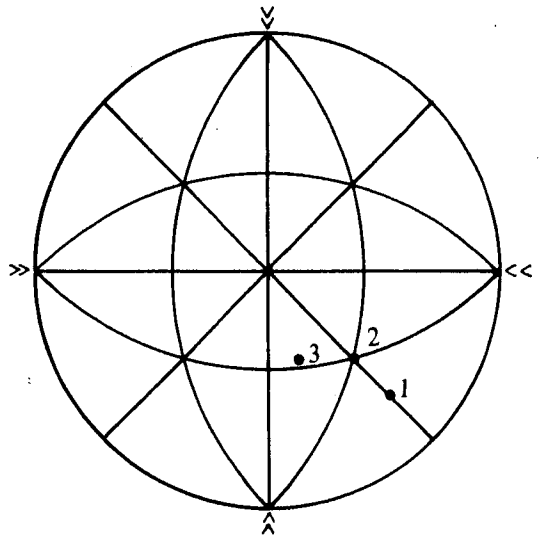
(A) 45% leucite and 55% K-feldspar
(B) 45% tridymite and 55% K-feldspar
(C) 45% tridymite and 55% leucite
(D) 55% tridymite and 45% leucite
(E) 55% tridymite and 45% K-feldspar

106. The minerals in which of the following pairs are polymorphs of each other?

(A) Anhydrite and gypsum
(B) Quartz and opal
(C) Celestite and barite
(D) Kyanite and sillimanite
(E) Rhodochrosite and smithsonite

107. Density may be used in ascertaining the composition of olivines because density

(A) increases linearly with iron content
(B) increases exponentially with forsterite content
(C) is the major factor that determines the proportion of iron in an olivine melt
(D) does not vary with olivine-bearing rock types, whereas iron content does
(E) can usually be determined more accurately by physical analysis than iron content can be by chemical analysis



108. On the stereogram above, the great circles represent planes inclined 45 degrees to the three axes (east-west, north-south, and vertical), and all three points on the stereogram (1, 2, 3) have Miller indices of 111. Which of the following correctly identifies the crystal system each point represents?

	1	2	3
(A)	Tetragonal	Isometric	Orthorhombic
(B)	Orthorhombic	Tetragonal	Monoclinic
(C)	Isometric	Orthorhombic	Triclinic
(D)	Monoclinic	Isometric	Triclinic
(E)	Monoclinic	Isometric	Monoclinic

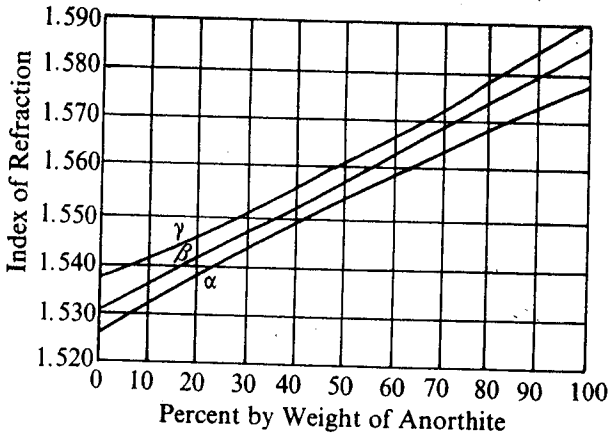
109. Undersaturated igneous rocks are characterized by

(A) a deficiency of Al_2O_3
(B) a deficiency of SiO_2
(C) a deficiency of alkalies
(D) an absence of hornblende, biotite, or muscovite
(E) an absence of hydrothermal alteration

110. Which of the following associations of minerals and structural types is correct?

(A) Biotite and muscovite. .double chain structure
(B) Olivine and chondrodite. .single chain structure
(C) Hornblende and rhodonite. .sheet structure
(D) Diopside and wollastonite. .single tetrahedron structure
(E) Leucite and orthoclase. .framework structure

Questions 111-113 relate to the following graph, which shows the index of refraction of a feldspar as a function of the pecent by weight of anorthite present.



The questions are concerned with a feldspar that is 30 percent albite and 70 percent anorthite by weight.

111. The smallest index of refraction of this feldspar is

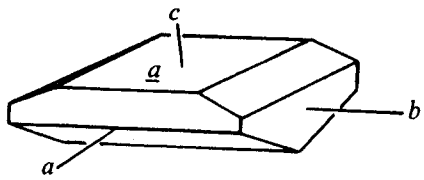
(A) 1.573 (B) 1.569 (C) 1.564
(D) 1.551 (E) 1.543

112. The birefringence of this feldspar is

(A) 0.009 (B) 0.007 (C) 0.004 (D) 0.002
(E) indeterminable from the graph

113. This feldspar is

(A) orthoclase
(B) perthite
(C) sodic anorthoclase
(D) calcic plagioclase
(E) oligoclase



114. The Miller index of face $\underline{a}$ of the crystal shown above is

(A) 010 (B) 001 (C) $h0\ell$
(D) 100 (E) $0k\ell$

115. Inclined extinction angles are used to identify

(A) glass
(B) monoclinic crystals
(C) tetragonal crystals
(D) hexagonal crystals
(E) isometric crystals

116. The family of primary minerals that produces the greatest bulk of clay minerals through weathering is

(A) quartz
(B) feldspar
(C) pyroxene
(D) calcite
(E) mica

117. Which of the following minerals will undergo the most significant changes when heated from 100° to 400°C?

(A) Montmorillonite (B) Quartz (C) Hematite (D) Albite (E) Kaolinite

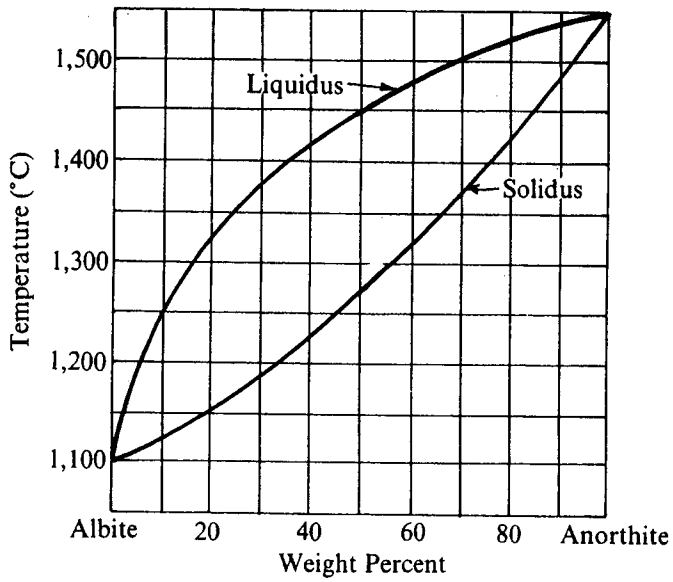
Questions 118-119. A chemical analysis of some clear crystalline calcite shows 5 mole percent MgO.

118. The most reasonable hypothesis to explain this finding is that the Mg is

(A) incorporated as MgO in solid solution
(B) a normal contaminant in carbonate minerals
(C) a constituent of hydrocarbon inclusions
(D) included as $MgCO_3$ in a mechanical mixture with $CaCO_3$
(E) present as Mg^{+2} ions in structural positions ordinarily occupied by Ca^{+2} ions

119. The most reasonable hypothesis to explain this finding could best be tested by

(A) grinding some crystals and making an x-ray diffraction analysis of the powder
(B) grinding a thin section and examining it with a petrographic microscope
(C) examining the crystals with a binocular microscope
(D) determining the specific gravity of the mineral
(E) repeating the chemical analysis



120. On the basis of the graph above, what would be the composition of the first crystals of feldspar to crystallize as a liquid of composition $Ab_{50}An_{50}$ cools?

(A) $Ab_{34}An_{66}$
(B) $Ab_{50}An_{50}$
(C) $Ab_{70}An_{30}$
(D) $Ab_{16}An_{84}$
(E) $Ab_{84}An_{16}$

B. PETROLOGY (Questions 121-139)

121. The types of volcanic rocks in which of the following groups are most characteristic of island arcs?

(A) Basalt, trachyte, granite
(B) Andesite, phonolite, dacite
(C) Basalt, andesite, dacite
(D) Rhyolite, granite, trachyte
(E) Leucite-basanite, basalt, peridotite

122. Which of the following does NOT involve the separation of liquids from liquids or solids during magmatic differentiation?

(A) Sulfide immiscibility
(B) Filter pressing
(C) Gravity settling
(D) Pneumatolysis
(E) Fractional crystallization

123. Which of the following statements is true of layered intrusives such as those at Skaergaard?

(A) They typically show evidence of convection in a magma chamber.
(B) They are thought to be the result of meteorite impact.
(C) They are restricted to granites and granodiorites.
(D) They are partially melted sedimentary rocks.
(E) They never show any evidence of differentiation.

124. In which of the following are the minerals listed in order of increasing resistance to chemical weathering?

(A) Hornblende, quartz, muscovite, biotite
(B) Calcic plagioclase, alkalic plagioclase, potash feldspar, quartz
(C) Biotite, hornblende, olivine, muscovite
(D) Potash feldspar, augite, biotite, olivine
(E) Muscovite, hornblende, augite, quartz

125. Which of the following statements is true of magmas?

(A) The melting temperature of dry basaltic magma increases with increasing load pressure in the mantle.
(B) The melting temperature of granite increases with increasing partial pressure of water.
(C) Magmas come from pockets of liquid left from an originally molten Earth.
(D) The most abundant volatile component in magmas is sulfur dioxide.
(E) Most magmas probably come from the liquid part of the Earth's core.

126. Which of the following is a likely association of minerals in a metamorphosed basalt?

(A) Albite, epidote, and staurolite
(B) Chloritoid, paragonite, and quartz
(C) Chlorite, kyanite, and almandine
(D) Hornblende and plagioclase
(E) Olivine, talc, and tremolite

127. Why do magnesian olivine and quartz NOT coexist in oversaturated igneous rocks that have undergone equilibrium crystallization?

(A) Such rocks do not have enough SiO_2 to produce free quartz after formation of silicate compounds with the available cations.
(B) At high temperatures there is a solid solution relationship between SiO_2 and Mg_2SiO_4.
(C) The existence of the mineral pair olivine plus quartz requires the additional formation of a feldspathoid such as nepheline.
(D) Magnesian olivine reacts with excess silica to form the pyroxene enstatite.
(E) The structure of olivine and the structure of quartz are incompatible.

128. Paired metamorphic belts consist of an inner, relatively high-temperature belt and an outer, relatively low-temperature belt. The latter is characterized by the

(A) widespread occurrence of sillimanite and/or andalusite
(B) abundance of granulites
(C) development of rocks of the blueschist facies
(D) presence of a contemporaneous convergent plate junction lying external to (i.e., oceanward from) the outer metamorphic belt
(E) pervasive emplacement of coeval granitic plutons

129. The ophiolite suite is a stratigraphic succession of rocks thought by many to represent the uppermost portion of an oceanic lithospheric plate. As studied on land, intact ophiolites consist of which of the following sequences, proceeding upward?

(A) Gabbro, granodiorite, granite
(B) Pillow basalt, sheeted diabase, radiolarian chert
(C) Pillow basalt, sheeted diabase, gabbro, peridotite
(D) Peridotite, gabbro, rhyolite, radiolarian chert
(E) Peridotite, gabbro, sheeted diabase, pillow basalt, radiolarian chert

130. Magmas of high viscosity have

(A) high silica concentrations
(B) high titanium concentrations
(C) high magnesium concentrations
(D) high iron concentrations
(E) low alumina concentrations

131. Which of the following mineral assemblages would most likely be found in an andesite?

(A) Albite, magnetite, augite, nepheline
(B) Andesine, hornblende, augite, magnetite
(C) Quartz, leucite, hornblende, magnetite
(D) Bytownite, olivine, garnet, magnetite
(E) Hornblende, augite, chlorite, epidote, labradorite

132. Which of the following mineral assemblages would be characteristic of a rock metamorphosed in the upper amphibolite facies?

(A) Quartz, muscovite, albite, andalusite
(B) Sillimanite, quartz, garnet, biotite, plagioclase
(C) Quartz, chlorite, albite, epidote
(D) Talc, chlorite, actinolite
(E) Calcite, epidote, actinolite

133. Which of the following is the product of the alteration of volcanic ash, and is useful in regional stratigraphic correlation?

(A) Spodumene
(B) Bentonite
(C) Attapulgite
(D) Gibbsite
(E) Illite

134. Which of the following rock types provides the richest source of calcium in the process of chemical weathering of primary crystalline rocks?

(A) Syenite
(B) Dacite
(C) Granite
(D) Gabbro
(E) Granodiorite

135. Which of the following statements is true of pegmatite and aplite?

(A) They are different names for the same type of subvolcanic stock.
(B) They differ mainly in grain size.
(C) They form very early in the crystallization of a pluton.
(D) They are never found together.
(E) They are commonest at oceanic spreading centers.

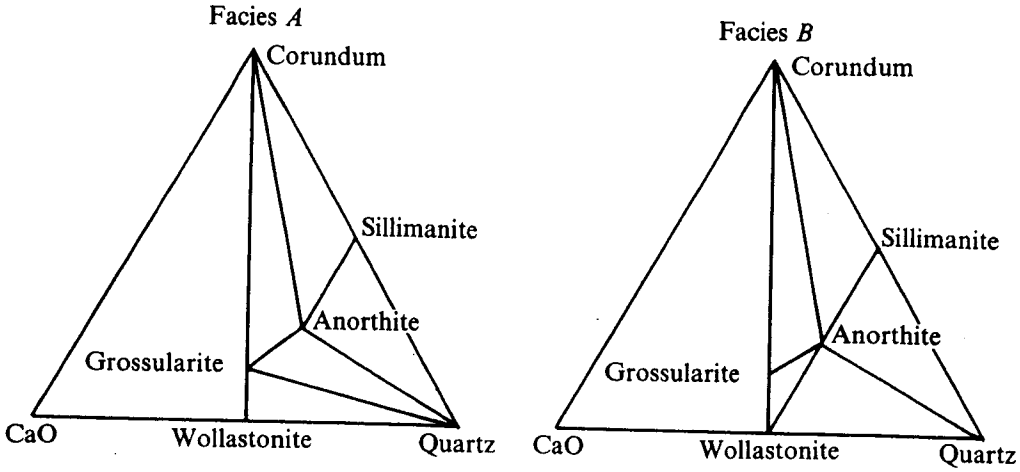
136. Soda metasomatism is the dominant petrologic process in which of the following?

(A) Serpentinization of peridotite
(B) Sericitization of nepheline syenite
(C) Chloritization of biotite schist
(D) Uralitization of pyroxenite
(E) Albitization of spilitic lavas

137. Which of the following is most closely associated with magmatic differentiation?

(A) A fissure vein of gold-quartz
(B) A titaniferous magnetite deposit
(C) A copper carbonate deposit
(D) A manganese oxide deposit
(E) A fluorspar deposit

Questions 138-139



138. Which of the following mineralogic equations best represents the change from facies *A* to facies *B*?

(A) Anorthite + sillimanite = wollastonite
(B) Wollastonite + sillimanite = anorthite
(C) Wollastonite + corundum = grossularite
(D) Grossularite + quartz = wollastonite + anorthite
(E) Wollastonite + anorthite = sillimanite + quartz

139. Which of the following is NOT a possible mineral assemblage in facies *A*?

(A) Grossularite, quartz, anorthite
(B) Grossularite, sillimanite, quartz
(C) Grossularite, anorthite, corundum
(D) Sillimanite, anorthite, quartz
(E) Sillimanite, anorthite, corundum

C. GEOCHEMISTRY (Questions 140-152)

140. Which of the following natural processes has been most important in the development of an oxygen-rich atmosphere on Earth?

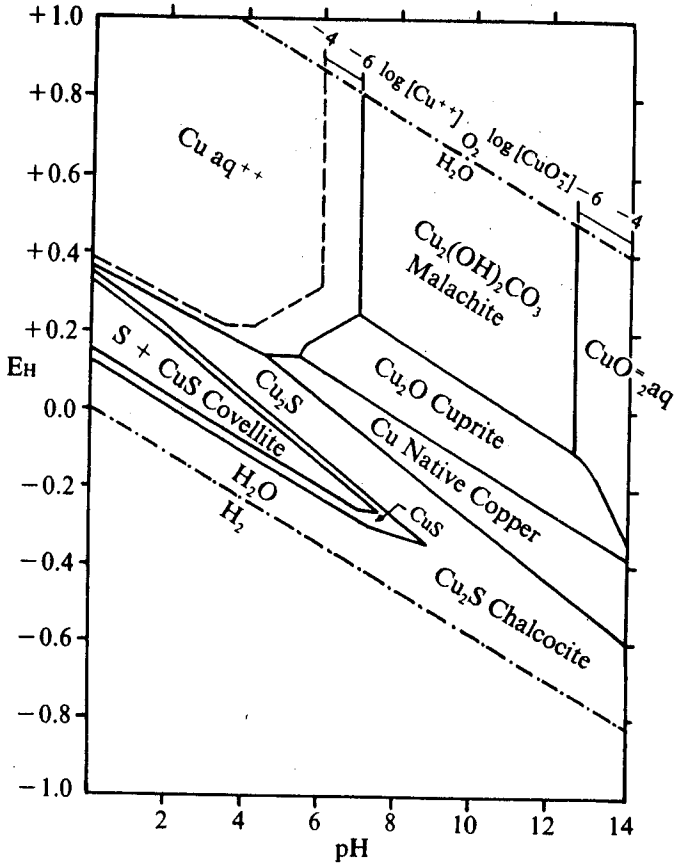
(A) Volcanism
(B) Selective loss of CO_2 to outer space
(C) Condensation of halogen gases in seawater
(D) Respiration of animal life
(E) Photosynthesis

141. The rates of chemical weathering of limestone used in buildings and monuments are greater today than in the past because

(A) the ozone content of the atmosphere has been reduced by gases from aerosol spray cans
(B) the climates of temperate regions are changing
(C) gamma radiation from sunspots has increased
(D) greater extremes of temperature in humid regions have caused more mechanical weathering from freezing and thawing
(E) CO_2 and other products from the combustion of fossil fuels have increased the acidity of moisture in the atmosphere

142. As the depth of burial increases, the progressive transformation of clay-rich sediments to shale and then to metamorphic rocks of successively higher grade is characterized by which of the following?

(A) The density of the rocks increases while the water content and grain size decrease.
(B) H_2O and CO_2 are driven out if metamorphism has taken place in a closed system.
(C) The mineral components change progressively to new forms that are stable at higher temperature and pressure.
(D) As the sediments are compressed, SiO_2 and Na_2O are removed in the water that is driven out.
(E) If the rock is part of a closed system, its mineral composition remains the same but the packing of grains becomes tighter.



143. The diagram above shows stability relations among some copper compounds in the system $Cu\text{-}H_2O\text{-}O_2\text{-}S\text{-}CO_2$ at 25°C and 1 atmosphere total pressure. On the basis of the diagram, one would expect which of the following to be true of the surface-tailings dump of a copper mine?

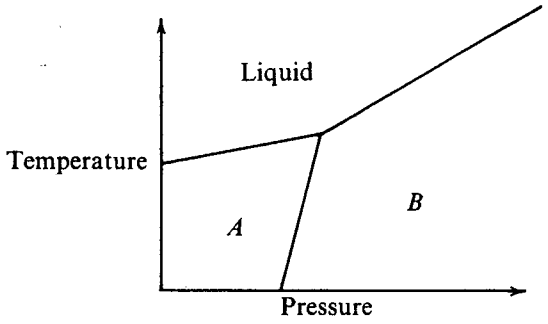
(A) Any copper present is entirely insoluble.
(B) Acid waters leach copper from the tailings.
(C) Cu_2O replaces malachite in the tailings.
(D) Any Cu_2S present is stable.
(E) Copper carbonate is readily removed in solution.

144. Which of the following statements about the carbon cycle is INCORRECT?

(A) Carbon is fixed according to the general equation $CO_2 + H_2O \longrightarrow CH_2O + O_2$.
(B) The atmosphere contains more CO_2 than the ocean.
(C) Oceanic carbon comes out of solution as carbonate.
(D) Over the last few decades the CO_2 concentration of the atmosphere has increased substantially.
(E) In order for the Earth's atmosphere to retain oxygen, carbon must be buried in sediments.

145. Of the following iron minerals, which is the LEAST stable in a humid, temperate climate?

(A) Pyrite (B) Hematite (C) Ilmenite
(D) Goethite (E) Magnetite



146. Two minerals, *A* and *B*, have stability fields as shown in the diagram above. From this diagram it is possible to conclude all of the following EXCEPT:

(A) *A* and *B* can coexist at different temperatures only if the pressures are also different.
(B) *A* and *B* can coexist with each other and with a liquid at only one temperature and pressure.
(C) *A* has a higher density than *B*.
(D) *B* has a higher melting temperature at higher pressures than at lower pressures.
(E) A reaction forming *A* from *B* at constant pressure will require an input of heat.

147. Significant amounts of calcium carbonate are NOT found in ocean waters deeper than about 4,000 meters because

(A) benthic foraminifera are rare at these depths
(B) pelagic foraminifera are scavenged by deep-sea, bottom-dwelling organisms
(C) carbon dioxide is less soluble in cold bottom waters that come from the Arctic and Antarctic oceans
(D) calcium carbonate is greatly overshadowed by rapidly sedimented turbidity-current deposits at these depths
(E) low temperature, high pressure, and low carbon dioxide content at these depths reduce the amount of available carbonate

148. A climatic change that would bring greatly increased rainfall to what was originally a hot arid region would cause the soils of that region to

(A) lose Na, K, Mg, and Ca and be residually enriched in Al and Fe
(B) become less acidic as vegetation increases
(C) be leached of highly soluble components, such as alumina
(D) develop layers of caliche near the top of the groundwater table
(E) develop a thicker *B* horizon and thinner *A* horizon

149. The equilibrium occurrence of kyanite, sillimanite, and andalusite in a pelitic schist would define

(A) the temperature as a function of pressure or vice versa
(B) the activity or partial pressure of H_2O during metamorphism
(C) the bulk composition of the host rock
(D) both the temperature and the pressure during metamorphism
(E) the metamorphic geothermal gradient

150. The residence time of oxygen in the Earth's atmosphere is about 2,000 years. This means that

(A) a mass of oxygen equivalent to about 1/2,000 of the Earth's atmospheric content is transformed into ozone every year
(B) a mass of oxygen equivalent to that presently in the Earth's atmosphere is removed and replaced in about 2,000 years
(C) the average molecule of atmospheric oxygen was provided by volcanic emission about 2,000 years ago
(D) the oldest oxygen molecules that make up the atmosphere have an estimated age of about 2,000 years
(E) in about 2,000 years half of the Earth's present mass of oxygen will be depleted and in about another 2,000 years half of that, and so on

151. Which of the following are the five most abundant elements in the universe?

(A) C, H, He, N, O
(B) C, H, He, N, Si
(C) Fe, H, He, N, O
(D) Ca, H, He, N, Si
(E) Ca, H, He, N, Na

152. Magma + limestone → calcic pyroxene + CO_2 + residual magma

As a result of the reaction indicated above, the residual magma will differ from the original magma in being

(A) less alkalic
(B) less silicic
(C) less hydrous
(D) more magnesian
(E) enriched in silica

D. ISOTOPE GEOLOGY (Questions 153-155)

153. Which of the following minerals is in general most useful for potassium-argon dating?

(A) Sylvite (B) Olivine (C) Biotite
(D) Albite (E) Nepheline

154. A geologist, who was interested in determining whether a particular body of granite was formed by the melting of old continental crust, could obtain an analysis of only one chemical feature of the rocks. The one that would be of most use would be

(A) ^{14}C
(B) K/Ar
(C) $^{87}Sr/^{86}Sr$
(D) Ho/Tm
(E) $^{18}O/^{16}O$

155. All of the following assumptions underlie the ^{14}C method of age determination EXCEPT:

(A) The rate of formation of ^{14}C by cosmic rays in the upper atmosphere is constant.
(B) The rate of mixing of the ^{14}C in the atmosphere-biosphere-ocean reservoir is rapid relative to the rate of radioactive decay.
(C) The rate of radioactive decay of ^{14}C is constant and unaffected by geochemical processes.
(D) Once the material containing the ^{14}C is removed from participation in life processes (e.g., death of a tree or deposition on the ocean floor of foraminifera), no further ^{14}C is added.
(E) The total quantity of carbon in the atmosphere remains constant.

E. ECONOMIC MINERAL DEPOSITS AND RESOURCES (Questions 156-159)

156. In which of the following are the current energy resources of the United States listed in order of decreasing abundance?

(A) Geothermal sources, coal, hydrocarbons
(B) Geothermal sources, hydrocarbons, coal
(C) Hydrocarbons, geothermal sources, coal
(D) Hydrocarbons, coal, geothermal sources
(E) Coal, hydrocarbons, geothermal sources

157. All of the following conditions favor formation of commercial bauxite EXCEPT

(A) high humidity and abundant rainfall
(B) warm climate
(C) sparsity of quartz
(D) abundance of ferruginous minerals
(E) good drainage

158. Which of the following groups correctly associates a nonmetallic material, its geologic occurrence, and its principal industrial use?

(A) Phosphorite—marine sediment—fertilizer
(B) Bentonite—volcanic eruption—abrasive
(C) Novaculite—hot springs—source of lubricants
(D) Andalusite—placer deposits—source of aluminum
(E) Asbestos—granite—insulation

159. Which of the following groups of minerals is diagnostic for the oxidized zone of a deeply weathered, primary, base-metal sulfide vein?

(A) Smithsonite, malachite, anglesite
(B) Calcite, fluorite, pyrite
(C) Limonite, realgar, niccolite
(D) Covellite, barite, analcite
(E) Zoisite, molybdenite, topaz

CLASSIFICATION SETS

Directions: Each group of questions below consists of five lettered headings followed by numbered questions. For each numbered question, select the one heading that best answers the question. One heading may be used once, more than once, or not at all in each group.

STRATIGRAPHY

Questions 160-162

(A) Ash layer
(B) Graded bedding
(C) Missing faunal zone
(D) Diastem
(E) Soil profile

160. Which is most likely to be associated with turbidite sequences?

161. Which is the most precise criterion for time correlation?

162. Which indicates a subaerial episode in the sedimentary record?

ECONOMIC MINERAL DEPOSITS AND RESOURCES

Questions 163-165 pertain to the following types of mineral deposits.

(A) Hydrothermal
(B) Sedimentary
(C) Metamorphic
(D) Magmatic
(E) Metasomatic

163. To which type do galena deposits belong?

164. To which type do placer gold deposits belong?

165. To which type do most chromite deposits belong?

SEDIMENTOLOGY

Questions 166-168 relate to the following types of sediment.

(A) Clastic sediment
(B) Biogenically precipitated sediment
(C) Chemically precipitated sediment
(D) Volcanic sediment
(E) Cosmic sediment

166. Trona is an example of which type of sediment?

167. Travertine is an example of which type of sediment?

168. Loess is an example of which type of sediment?

PETROLOGY

Questions 169-171 pertain to the following five sets of minerals.

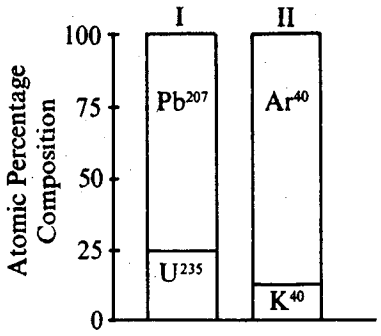
(A) Microcline, plagioclase, quartz
(B) Andesine, hornblende
(C) Quartz, chlorite, illite
(D) Kyanite, muscovite, quartz
(E) Olivine, enstatite, diopside

169. Which set contains the essential minerals of a granite?

170. Which set contains the essential minerals of ultra-basic rocks?

171. Which set contains the minerals commonly found in a shale?

Questions 172-173 are based on the accompanying graph and information on half-lives. The graph shows the atomic pecentage compositions of specimens I and II. Assume specimens I and II contained no lead or argon initially.



Half-lives:

U^{235}-Pb^{207}: 0.71 billion years

K^{40}-Ar^{40}: 1.3 billion years

(A) 1.4 billion years
(B) 2.1 billion years
(C) 2.6 billion years
(D) 3.9 billion years
(E) 5.2 billion years

172. What is the age of specimen I?

173. What is the age of specimen II?

SAMPLE QUESTIONS ANSWER KEY

I. Stratigraphy, Sedimentology, Paleontology, Geomorphology, and Hydrology

A. Stratigraphy

1. C
2. D
3. A
4. C

B. Sedimentology

5. D
6. B
7. E
8. D
9. D
10. C
11. C
12. B
13. A
14. E
15. A
16. B
17. E

C. Paleontology

18. A
19. A
20. B
21. C
22. B
23. B
24. D
25. D
26. D
27. B
28. E
29. D
30. A
31. A
32. D

D. Geomorphology

33. D
34. C
35. C
36. A
37. E
38. E
39. C
40. B
41. A
42. A

E. Hydrology

43. D

F. General, including oceanography

44. D
45. D
46. B

II. Structural Geology and Geophysics

A. Structure — field relations

47. D
48. E
49. D
50. B
51. D
52. C
53. A
54. C
55. C
56. C
57. D
58. C
59. E
60. E
61. B
62. D
63. A
64. E
65. A

B. Structure — dynamics

66. A
67. B
68. C
69. B
70. B
71. E
72. B
73. E
74. A

C. Tectonics

75. B
76. E
77. D
78. B
79. A
80. D
81. B

D. Isostasy, gravity, and magnetism

82. E
83. A
84. E
85. B
86. C
87. E
88. C
89. B
90. A
91. B

E. Earthquakes and seismology

92. B
93. A
94. C
95. B
96. A
97. E
98. D

F. Heat and electrical properties

99. A
100. C
101. E
102. C

G. General, including planetology

103. E
104. C

SAMPLE QUESTIONS ANSWER KEY (cont.)

III. Mineralogy, Petrology, and Geochemistry

A. Mineralogy

105. B
106. D
107. A
108. A
109. B
110. E
111. C
112. A
113. D
114. B
115. B
116. B
117. A
118. E
119. A
120. D

B. Petrology

121. C
122. D
123. A
124. B
125. A
126. D
127. D
128. C
129. E
130. A
131. B
132. B
133. B
134. D
135. B
136. E
137. B
138. D
139. B

C. Geochemistry

140. E
141. E
142. C
143. B
144. B
145. A
146. C
147. E
148. A
149. D
150. B
151. A
152. B

D. Isotope geology

153. C
154. C
155. E

E. Economic mineral deposits and resources

156. E
157. D
158. A
159. A

Classification Sets

Stratigraphy

160. B
161. A
162. E

Sedimentology

166. C
167. C
168. A

Isotope geology

172. A
173. D

Economic mineral deposits and resources

163. A
164. B
165. D

Petrology

169. A
170. E
171. C