A Dictionary of Earth Sciences

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A DICTIONARY OF EARTH SCIENCES

Edited by

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Key to Symbols

Asterisks before words in the text denote cross-references to entries that will provide additional information. Entries are defined under the most commonly used term, with synonyms shown in brackets.

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aa. A *lava with an extremely rough spinose surface. *Compare* block lava, pahoehoe.

abandoned cliff. *See* cliff.

ablation. The disappearance of snow and ice by melting and evaporation. This can refer to ice crystals or snow flakes in the atmosphere but is most commonly used for glacier ice and surface snow cover, when it can also include avalanching. The rate of ablation is primarily controlled by air temperature but sunshine, rainfall, humidity, and wind speed also affect the process.

ablation till. *Till material formerly present on the ice surface and subsequently deposited as a result of the melting of the ice beneath. These deposits tend to contain relatively little fine material since this may be removed by meltwater prior to deposition. *Compare* lodgement till.

Abney level. A simple surveying instrument for measuring slope angles. The level is held by hand, objects being viewed through a sighting tube. The observer may stand at the top or bottom of a slope, but must sight onto a point at a height equivalent to his eye-level. Once an object is sighted, adjustment is made to a tilting spirit level, an image of the bubble being visible in the sighting tube. When the bubble image coincides with the object sight the angle of slope can be read off an attached scale, which is provided with a vernier to permit reading down to ten minutes of arc. The instrument is not very accurate, but is small and quick to use.

abnormal (accelerated) erosion. Erosion acting faster than normal as a result of the removal of the vegetation cover by human agencies. It is abnormal in the sense that it is superimposed upon natural processes. *See also* human influence on geomorphology, blowout.

abrasion. The wearing away of rocks by an agent of transportation charged with a load of already eroded material, which acts as a tool for cutting, grinding, scratching, and polishing. All the major transportation agents (running water, wind, moving ice, and sea waves and currents) can abrade so long as they carry debris. Abrasion by water and ice characteristically produces rounded forms, and abrasion by ice also produces striations, whilst the sand-blasting effect of wind abrasion is most effective in a narrow zone just above ground level, resulting in undercut features. As abrasion takes place, the corresponding reduction in size of the initial load debris is known as *attrition. A distinction is sometimes made between abrasion and *corrasion*, which refers to the erosional processes that result in abraded rock surfaces.

absolute temperature. A temperature scale based on the coldest temperature that is physically possible. This absolute zero of temperature is -273.15 °C, but for meteorological purposes the absolute temperature is taken as the Celsius temperature plus 273°, so that the freezing point of water is 273° and boiling point 373°. Formerly measured in degrees absolute (°A), it is now measured in *kelvins.

absorption (in meterology). The conversion of short- or long-wave radiation to a different form of energy by gases in the atmosphere. Absorption is highly selective in terms of wavelength; some wavelengths are entirely absorbed and others are totally unaffected. The main atmospheric gases, oxygen and nitrogen, are not very important as absorbers of radiation, but minor gases such as carbon dioxide, water vapour, ozone, and nitrous oxide have a significant effect. *See also* atmospheric window.

abyssal plain. An extremely smooth portion of the deep-sea floor. The gradients across abyssal plains fall within the range of 1:1000 to 1:10 000, which means that variations in depth amount to only a few metres. This remarkable degree of flatness has come to light because of deep-sea photographs and high-precision sounding

techniques. In the Atlantic Ocean, abyssal plains range between 200 and 400 kilometres in width, but they can be several hundred kilometres wide. They tail upwards into the continental rise and frequently, in a seaward direction, merge into abyssal hills. Their sediments are varied; while most are thinly veneered with pelagic sediment, perhaps globigerina ooze and red clay, they also display sediments and plant and animal remains that normally characterize shallow-water environments. The reason for this may be the operation of *turbidity currents.

abyssal rocks. Intrusive igneous rocks formed deep within the earth's crust.

abyssal zone. A zone of greatest ocean depth, lying seaward of and deeper than the *bathyal zone of the continental slope, that is below a depth of some 1000 m, and including the deeper parts of the oceans and the deep-sea trenches. Lying between the abyssal and bathyal zones is the *continental rise, which is often bordered on its seaward flank by abyssal plains and abyssal hills. The *pelagic-abyssal environment, which is not reached for at least several hundred kilometres from the coast, globally represents an area of 250×10^6 sq. km, i.e. roughly half the area of the earth. Few organisms live in these depths, where pressure is high and light does not reach, and deposition of sediment is very slow.

accelerated erosion. *See* abnormal erosion.

acceleration of free fall (acceleration due to gravity). The acceleration (g) of a body falling freely in a vacuum in the earth's gravitational field. The standard value is 9.806 65 m s^{-2}, although actual values depend on the distance from the earth's centre of mass.

accessory mineral. A mineral that is present in small quantities in a rock and does not affect the overall character of that rock for classification purposes.

acclimatization. The process by which man becomes adapted to living in a markedly unfamiliar climatic regime. This normally refers to a change to hot and humid or especially cold climatic conditions. If acclimatization has not taken place, severe physiological stress may result. The full process may take up to ten years.

accordant (conformable). Denoting a drainage pattern that is controlled by the structures over which it flows. Actual patterns vary greatly, depending on the nature of the structures or lithologies. *Compare* discordant (def. 2).

accordian folding. A type of folding in rocks, in which the beds of the hinge area are markedly thickened and sharply folded, whilst on the limbs the beds are straight and of uniform thickness.

accretion. 1. The process of ice crystal growth by collision with water droplets in clouds. This is one of the mechanisms by which minute cloud droplets achieve sufficient size to give rainfall.
2. *See* nucleation.

accumulated temperature. A method of indicating the excess or deficit of temperature with reference to a specified value for a specified period. Two temperature bases that have been frequently used are 6 °C for the commencement of plant growth and 16 °C for heating requirements. The accumulated temperature is calculated by taking the number of hours in a specific period the temperature was above or below the set value and multiplying by the mean temperature during this time to give the number of degree hours. More commonly, daily or monthly values of accumulated temperature are obtained from daily or mean values rather than hourly ones.

achondrite. A stony meteorite that does not contain *chondrules. *Compare* chondrite.

acicular. Denoting a crystal having a needle-like habit. *See* crystal habit.

acid brown soils. Soils found in the *brown earth zone on base-deficient parent materials. They are strongly acid, with a moder humus, and although the B horizon is more clearly differentiated by colour than in the true brown earth there is no appreciable eluviation of clay or iron oxides. They are typically found on the hard sediments in N and W Britain. With time it seems likely that these soils would become podzolic brown earths.

acid rocks. The dominant chemical constituent of igneous rocks is SiO_2, which typically ranges from 35-75% (by weight). Arbitrary divisions are made as follows: acid—SiO_2 >66%, intermediate—SiO_2 55-66%, basic—SiO_2 45-55%, and ultrabasic—SiO_2<45%. These strict divisions have been largely abandoned but the general descriptive terms acid, basic, etc., remain. In current usage, an acid rock contains in excess of about 10% free quartz, e.g.: granite, granodiorite, rhyolite.

acid soil. Soil acidity is measured on the pH scale, which is related to the concentration of hydrogen ions in the soil. A neutral soil is given a pH value of 7.0; if the value is less than this it is termed an acid soil and if greater an alkaline soil. Thus there is an inverse relationship between pH value and the concentration of hydrogen ions. Acid soils develop where, for some reason, there is a lack of the exchangeable bases in the soil, such as calcium and sodium. The bases have been largely replaced by the two cations hydrogen and aluminium, which control soil acidity. Possible acid-forming factors are leaching, organic matter containing few bases, and an acid parent material. Acid soils are therefore particularly common in the humid tropics and the humid temperate lands. Examples of typical acid soils are podzols, brown earths, and latosols. From the agricultural viewpoint most cultivated crops will thrive on mildly acid soils.

acmite (aegirine). *See* pyroxene.

actinolite. A monoclinic *amphibole.

actinomycetes. Aerobic microorganisms that have a filamentous habit as do fungi. They are next in abundance to bacteria in the soil. Optimum conditions are a moist well-aerated soil with a pH between 6.0 and 7.5. They are more prolific than bacteria and fungi in drier areas and are important also in that they can decompose the more resistant soil organic matter.

Actinopterygii. Ray-finned bony fish in which the paired fins are not fleshy (*compare* Crossopterygii) but have narrow bases and are supported by thin fin rays. The Actinopterygii also have a single dorsal fin. The group includes the modern *Teleostei. *See also* Osteichthyes.

active layer. *See* permafrost.

actualism. *See* uniformitarianism.

actuopalaeontology. The branch of palaeontology in which investigations into modern organisms, including their effects and remains in modern environments, are directed toward the understanding of fossil analogues. Based upon uniformitarian principles (*see* uniformitarianism), actuopalaeontology provides a means of relating various *trace fossils to the particular animals from which they are derived and of understanding the changes that an organism undergoes between death and fossilization (*see* taphonomy, thanatocoenosis). *Biostratonomy is one aspect of actuopalaeontology.

adamellite. A variety of granite consisting of about equal proportions of potassium feldspar and sodic plagioclase feldspar together with one or more ferromagnesian minerals.

adiabatic. Denoting an atmospheric process in which there is no exchange of heat between the system and its environment. In the more rapid exchanges, such as thermals rising from the ground surface, this is a reasonable

approximation. In these circumstances, the change of temperature of rising air is determined by the physical properties of the air and the external pressure. As air pressure decreases with height above the ground surface, rising air expands, and exerts mechanical work on its environment. This necessitates a loss of heat energy from the rising air and its temperature falls. The rate of fall of temperature in an adiabatic process is constant for our atmospheric composition, being 0.98°C/100 metres, and is known as the *dry adiabatic lapse rate.

adjacent seas. Marginal seas and inland seas. They lie adjacent to the oceans but generally they are much smaller. Because many adjacent seas are largely encircled by land, the characteristics of the water and sediments they contain, and to a certain extent their topography, are strongly influenced by the landmass, for example in the amounts and nature of terrigenous sediments transported down rivers to the coast and the climatic effects associated with the land-sea margin.

adularia. A variety of alkali *feldspar.

advection. The horizontal component in the transfer of air properties. For example, the heat and water vapour content of the air at the earth's surface varies appreciably and by the wind systems these properties are transferred to other areas. With winds from tropical latitudes there is advection of warm air, and from polar latitudes, advection of cold air.

advection fog. Fog formed by the horizontal transfer of moist air over a cold surface, which sufficiently cools the lower layers of the atmosphere to give saturation and condensation. In summer it occurs over cool seas, such as the North Sea, the Labrador area, and off the coast of California, frequently affecting the adjacent coasts. In winter the advection of warm moist air over a cold snow-covered ground can also produce this type of fog.

aegirine (acmite). A sodic clinopyroxene. *See* pyroxene.

aegirine-augite. *See* pyroxene.

aeolian erosion. The direct erosive action of wind. This is the least important aspect of wind action, generally of little consequence in landscape formation when compared with the role of wind transport and deposition. Sand blast, from the impact of saltating grains, is limited to below one metre or so from the ground surface; it can undercut rocks leaving pedestals, although in some instances increased weathering at the foot of the rock weakens it beforehand.
More significant than aeolian erosion by abrasion is the production of *deflation hollows. These can reach 100 km across, and although partly due in some cases to faulting or rock solution, they are mainly due to wind removal of preweathered material down to the water table, which halts further removal and produces oases.

aeolian forms. Landforms produced by material transported by wind. Large-scale features include dunes, sand shadows, and sand sheets, while small-scale features include sand ripples and ridges. Sand shadows, unlike true dunes, are deposited in the shelter of an obstacle, while sand sheets or seas are amorphous sheets with gentle swellings reaching 3–6 metres. Ripples are the products of irregularities in the surface over which the sand is passing: these initiate local concentrations of sand grain impacts on the slopes facing the wind, which become built up as ripples. Further, each ripple acts as a take-off point for grains in *saltation, and since the average length of travel per jump is related to wind speed, an even repetition of areas of concentrated grain impacts occurs downwind, leading to regular ripple patterns.

aeolian transport. The movement of sediment by wind. Below a threshold of 16 km per hour wind is incapable of moving sand, but thereafter sand move-

ment rises as a cubic function of wind speed. Short periods of high-velocity winds are therefore very much more effective than longer periods of gentle winds.

Aeolian transport takes place concurrently in three forms: suspension, *saltation, and surface creep. A small proportion of grains of less than 0.2 mm in diameter can be carried wholly in suspension; the particle is totally buoyed up by the rising eddies in the air and carried along parallel to the air stream. Surface creep accounts for about 25% of actual sand movement, and involves the movement of grains of coarse sand along the surface by the impact of the saltating grains. Saltation accounts for about 75% of sand flow and involves the bouncing of grains along the surface at heights of less than 1 metre, and mostly within 200 mm of the ground surface.

aerodynamic roughness. An index of the nature of airflow near the ground surface. A surface is aerodynamically smooth if there is a layer of air immediately above it that has laminar flow. However, in meteorological terms, nearly all surfaces are aerodynamically rough, producing turbulent flow down to the ground surface, even for the lightest winds.

aeronautical chart. A form of map produced essentially for air navigation or pilotage. In addition to showing the relevant topographical features, such as contours, vegetation, roads, and cultural detail, the map shows supplementary information for specialized use, such as detailed vertical obstruction information, flight areas, air corridors, etc.

aeronomy. The science of the upper atmosphere, where dissociation and ionization of gas molecules takes place. The lower limit for these processes to occur is about 30 km. As the relationships between the upper and lower atmosphere are as yet little understood, there has been considerable research recently into the possible effects of these upper levels in tropospheric weather.

aerosol. A particle of matter that is larger than a molecule but small enough to remain suspended in the atmosphere. Aerosols may be solid or liquid and play an important part in many atmospheric processes, such as precipitation formation, atmospheric electrification, radiation balances, and visibility. The origins of aerosols are diverse. Over sea areas, sea spray provides large salt nuclei and over land, weathering dusts of clay particles are probably the major source.

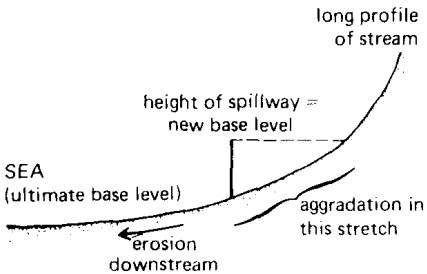
aftershocks. A series of minor shocks or vibrations that follow the main series of earthquake shocks. In general they originate at or near the focus of the main earthquake as a result of the readjustment of rocks that have overreacted during the main period of movement. Depending upon the size of the earthquake they can continue for a few days or months.

agate. A banded or concentrically zoned *cryptocrystalline form of silica. *See* silica minerals.

age. An interval of geological time in the Chronomeric Standard scale of chronostratigraphic classification (*see* chronostratigraphy). The equivalent Stratomeric Standard term, indicating the body of rock formed during this time, is the *stage. Ages may be grouped together to form *epochs and may themselves be comprised of several *chrons.

ageostrophic wind. The vector difference between the actual and the geostrophic wind. Without an ageostrophic component there would be no changes in pressure systems and atmospheric circulation would be a perfect balance between the pressure gradient and the *Coriolis force.

agglomerate. A mixture of coarse angular fragments of rock and finer-grained material formed during a volcanic explosion. *See* pyroclastic rocks.



Aggradation in a dammed stream

aggradation. The raising of the level of the land surface, especially by rivers. The cause of aggradation is incompetence (*see* competence) or incapacity (*see* capacity) of the river to transport its load, leading to deposition. This may arise through an increase in the volume of load supplied to the river, a loss of speed or volume of flow, or most commonly a rise in base level. In S England, the rise in sea level since the end of the Pleistocene has resulted in aggradation in many rivers, producing buried channels; for example, the River Arun in Sussex has aggraded deposits over 30 metres deep in places. Another common cause of aggradation is the damming of a stream, artificially creating a new base level for the upper reaches of a river. Originally graded to sea level, the upper reaches will aggrade to the new base level, the height of the dam's spillway. *See also* degradation.

agmatite. A migmatite in which melanocratic material occurs as angular inclusions in a leucocratic granitic host, giving an overall appearance resembling a breccia.

Agnatha. Primitive jawless fish, from which all more advanced vertebrate types have presumably evolved. Modern species are few and represent groups unknown as fossils. The diverse extinct forms can be grouped together as the *Ostracodermi, which were abundant in the Silurian and Devonian and are used in stratigraphic *correlation. *Compare* Gnathostomata.

air. The mixture of gases in the atmosphere. Its composition is almost uniform throughout the troposphere and is shown in the table below. Only water vapour and carbon dioxide vary appreciably, the former in relation to evaporation and precipitation and the latter through plant photosynthesis.

Composition of Air (% by volume)

nitrogen (N_2) 78·08	krypton (Kr) $1{\cdot}14 \times 10^{-4}$
oxygen (O_2) 20·95	xenon (Xe) $8{\cdot}7 \times 10^{-5}$
carbon dioxide (CO_2) 0·03	ozone (O_3) 1×10^{-5}
argon (Ar) 0·93	nitrous oxide (N_2O) 3×10^{-5}
neon (Ne) $1{\cdot}82 \times 10^{-3}$	water (H_2O) variable, up to 1·00
helium (He) $5{\cdot}24 \times 10^{-4}$	hydrogen (H_2) 5×10^{-5}
methane (CH_4) $1{\cdot}5 \times 10^{-4}$	

air mass. An area of the lower atmosphere with similar properties of temperature and moisture in the horizontal field. At the margins of the air mass, temperature gradients become steep at a transition zone known as a *front. The uniformity of properties is achieved by prolonged contact with the underlying surface and little horizontal or vertical mixing. These requirements are experienced in areas of high pressure or anticyclones, which are the main source areas for air masses. Away from their source areas, air masses undergo modification by coming in contact with different surfaces with the result that in a short period of time they can become indistinguishable. As most parts of the world represent modification zones rather than source areas, air mass terminology is less frequently used than formerly. There have been many attempts to classify air masses, but the most frequently quoted is that by Bergeron. Two basic air masses are identified on thermal properties—polar (P) and tropical (T), and two by moisture categories—maritime (m) and continental (c). The temperature of the air mass

relative to the surface over which it is passing is included as warm (w) or cold (k) to give a wide range of combinations—mPw, cTk, etc. Willett modified this system slightly to add stable (s) or unstable (u) to indicate the likelihood of precipitation in the system. Other classifications distinguish equatorial, monsoon, and Arctic (or Antarctic) but difficulties can arise in identification.

air stream. A flow of air that is not necessarily homogeneous but has a distinctive origin. Air streams are therefore distinguished by their direction of approach rather than assuming any specific thermal or stability properties. The mid-latitude westerlies can be regarded as being a mixture of slightly baroclinic air streams bounded by sharp frontal zones.

Airy's hypothesis of isostacy. George Bedell Airy proposed that in order for isostatic equilibrium to exist, mountain ranges must have roots proportional to their height, i.e. the highest mountains have the deepest roots. These roots are composed of sialic material and displace an equivalent volume of sima, thereby causing the gravity anomalies present near mountain chains.

Aitken nucleus. *See* nucleus.

Aitoff's equal-area projection. A cylindrical map projection of a hemisphere. The major axis, the equator, is twice the length of the minor, central meridian, axis. The projection is bounded by an ellipse. The main characteristics of this projection are that it is an equal-area projection and landmasses near the centre of the area covered are of quite good shape, though the distortion increases towards the east and west limits of the projection.

albedo. An index of reflection comprising the ratio of reflected radiation to the total incident radiation. Usually this value is expressed in a percentage form for visible wavelengths. Typical values for surface albedo are: forest 5–10%, wet soil 10%, sand 20–30%, grass 25%, old snow 55%, concrete 17–27%, fresh snow 80%. Water surfaces vary from about 5% with high sun and calm seas to 70% at low elevation and rough seas. The planetary albedo of the earth measured from artificial satellites is approximately 34%, which means that over one third of the sun's radiation is returned to space without a change of wavelength.

albite. A sodic plagioclase *feldspar.

Aleutian Low. The mean low pressure centre in the N Pacific Ocean. It represents a statistical average of pressure value and location, which in turn are determined by the tracks of the depressions and the point at which they reach their lowest pressure. It is most marked in the winter.

alfisol. One of the ten soil orders of the *Seventh Approximation, covering pedalfers that are equivalent to the grey-brown podzolic, grey-wooded, grey-forest, sol lessivé, degraded chernozem, and planosol soils of the old American classification. They are found in the humid regions of the world under deciduous woodland or grassland vegetation. The dominant soil-forming process is leaching, which is more intense in these soils than in the inceptisols but less than in the spodosols. They are productive soils and favour the more common agricultural crops.

Algae. A group of primitive and largely aquatic plants that have no flowers, leaves, or vascular system. The group includes both microscopic plants, such as the *diatoms, as well as the multicellular seaweeds, which may grow to a large size. Algae are often subdivided into different categories; for example, single-celled forms are sometimes considered as belonging to a separate kingdom, the Protista.

The only geologically significant algae are those having hard parts, which may form bioherms, either by trapping sediment or by secreting massive laminated structures of calcium carbonate. Such structures commonly constitute lower Palaeozoic *reefs. Precambrian struc-

tures called *stromatolites may also be of algal origin.
Compared with bacteria, fungi, and actinomycetes, algae are relatively unimportant in soils but certain blue-green algae do fix atmospheric nitrogen. They are often pioneers in colonizing new ground and may number up to 100 000 per gram of dry surface soil.

alidade. A surveying instrument used for sighting onto objects of detail and for defining the rays to be drawn to them in *plane table surveying. The alidade is basically a ruler of metal or wood with a vertical slit sight at the observer's end and a vertical stretched wire sight at the other. (A telescope is fixed parallel to the ruler in more sophisticated types of alidade.) The ruler edge is placed against the point marked on the table over which the apparatus is standing, and detail to be fixed is sighted onto. A ray is then drawn on the plane table sheet along the ruler edge. Though either side of the ruler may be used initially, once one ray has been drawn, only that side may be used until that sheet is completed.

alkali (alkaline) (in petrology and mineralogy). Denoting igneous rocks and minerals that have high contents of the alkali metal oxides, Na_2O and K_2O. For a given silica content such rocks are relatively richer in sodium and potassium and poorer in calcium compared with calc-alkaline rocks. *See* alkali basalt, alkali gabbro, nephelinite, ijolite, granite.

alkali basalt. A basic undersaturated volcanic rock that is the fine-grained equivalent of *alkali gabbro. The essential minerals of all basalts are plagioclase feldspar of labradorite-bytownite composition and pyroxene. In alkali basalts the pyroxene is augite or titanaugite and olivine is present in abundance. Olivine is frequently rimmed or pseudomorphed by the alteration products iddingsite and/or serpentine. Small amounts of alkali feldspar and/or feldspathoid (nepheline or analcite) may be present. Alkali basalts are typically porphyritic. Basalts containing large plagioclase phenocrysts are referred to as *feldsparphyric* or *big feldspar* basalts. Those rich in olivine and augite are termed picrite basalts. Oceanite and ankaramite are varieties in which olivine and augite respectively have become concentrated.
Alkali basalts are usually holocrystalline and have ophitic or intergranular textures. Nodules of gabbro and peridotite are often found in alkali basalt lavas.
With an increase in the amount of nepheline to greater than 10%, alkali basalts pass into basanites (olivine-bearing) and tephrites (olivine-free). In some rocks, the place of nepheline is taken by analcite or leucite and such terms as analcite-basanite and leucite-tephrite are appropriate. *See also* basalt.

alkali feldspars. A series of minerals with composition varying between the two end-members albite ($NaAlSi_3O_8$) and orthoclase ($KAlSi_3O_8$). *See* feldspar.

alkali gabbro. Alkali gabbros and syenogabbros are basic plutonic rocks containing, in addition to the normal gabbro mineralogy, alkali feldspar and/or feldspathoids. Syenogabbros contain approximately equal amounts of alkali and plagioclase feldspar with *titanaugite, *analcime, and/or *nepheline plus or minus olivine. Having more sodium and potassium than gabbros, syenogabbros are, as the name implies, related to *syenites.
Essexite consists of labradorite, titanaugite, and olivine plus small amounts of nepheline and/or analcime. Alkali feldspar, apatite, and ilmenite may also be present. *Teschenite* and *crinanite* are analcime-bearing varieties from which nepheline is excluded. *Theralite* is a nepheline-bearing gabbro containing no analcime.
Kentallenite is a saturated rock containing augite, olivine, biotite, labradorite, and orthoclase and is equivalent to olivine-monzonite.
The names of the plutonic rocks are

applied to the medium-grained varieties of doleritic aspect but with the prefix *micro-*. The volcanic equivalents include basanites, tephrites, and trachybasalts.
Teschenite and theralite are found in differentiated sills and dykes.

alkaline soil. *See* acid soil.

allanite (orthite). *See* epidote.

Alleröd. A phase of warming of about 1000 years during the period of deglaciation after the Würm/Weichsel/Wisconsin ice age. In many parts of NW Europe this was followed by a sudden cooling from 8800 to 8300 B.C. The type-site from which the period takes its name is in Denmark.

allivalite. A gabbro consisting of olivine and plagioclase feldspar of bytownite-anorthite composition.

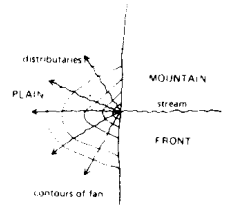
allochems. Discrete calcareous particles that have usually been transported at some stage, including *fossils, ooliths (*see* oolite), *intraclasts, and *pellets, found in *limestones; the terminology used in the petrographic description and classification of limestones is based upon these constituents and the matrix in which they are set (*see* micrite, sparite). Thus a limestone composed of fossil fragments set in a micrite matrix is a biomicrite; a pellet limestone with a sparite matrix is a pelsparite.

allochthonous. Denoting an isolated mass of rock displaced over a considerable distance from its original source by low-angle thrusting. *Compare* autochthonous.

allogenic (allothigenous). Denoting rock constituents that were formed at some distance from their present location, particularly minerals or rock fragments derived from existing rocks. *Compare* authigenic.

allotriomorphic. Denoting a rock in which the majority of crystals are euhedral. *Compare* idiomorphic, hypidiomorphic.

Alluvial fan



alluvial fan. A fan or cone of material deposited by a stream where it debouches from a mountain front onto a plain, with the apex of the fan at the point of emergence from the mountains. In its mountain tract, the stream will have been confined into a single flow in a rock-cut gorge, but on reaching the plain this control is lost, and it breaks up into a number of distributaries. This increases the wetted perimeter, or area of contact between water and land, and hence friction increases; with more of its energy used in overcoming friction, less is available for sediment transport, so deposition occurs, in the form of a fan. This is the direct landborne analogy to *delta formation, and is a landform characteristic of arid and semiarid environments.

alluvium. The products of *sedimentation by rivers, sometimes including deposits in estuaries, lakes, and other bodies of fresh water. It covers material of a wide range of *particle sizes, though in the British Standard classification it is restricted to the silt size fraction of 0.006–0.02 mm.
There is a marked decrease in the size of alluvial material down-valley, with finer material in the lower reaches. This may be due to *sorting, which leaves coarse material behind and carries finer material down-valley, or it may be due to progressive wear of the material as it travels downstream. Another cause may be that smaller valley-side slopes downstream supply a finer calibre of material to the stream.
Within the *floodplain alluvium (in the looser sense) varies in size from the finest clay and silt-sized material through sands to coarse angular gravels. The gravels form the basal portions of

alluvial valleys, and may have originated at the end of the *Pleistocene period under *periglacial conditions; in some rivers they are attributed to deposition within the channel in conditions in which severe scour removed the fine material. Silts, sands, and gravels are more important, constituting 75% of the Mississippi alluvium. Sands constitute the point bars formed on the inside of meander bends, and are an important constituent of levées. Silts and clays are deposited in the lee of point bars or as overbank deposits in times of flood, covering the far reaches of the floodplains with backswamp deposits.

almandine. *See* garnet.

alnoite. A basic or ultrabasic dyke rock composed largely of melilite and biotite with subordinate pyroxene, calcite, and olivine. Alnoite is found in ijolite-carbonatite complexes.

Alpine-Himalayan chain. A predominantly east-west trending orogenic belt, extending from Spain through Europe to S Asia. It was formed mainly in the Tertiary by the closure of the former Tethyan Ocean, mainly as a result of the northerly drift of the African continent. It consists of a series of igneous, metamorphic, and deformed sedimentary rocks, which now form the Alps and Himalayan Mountains.

altiplanation. A process associated with a *periglacial environment in which terraces or benches are cut in solid rock in hillside or summit locations. The weathering and erosion of the rocks is achieved by a combination of *frost shattering, *solifluction, and *congeliturbation. Terrace formation is probably initiated by the production of a *nivation hollow in hard rock, the backwall of which then retreats, causing an enlargement of the flat or gently sloping terrace in front. Altiplanation terraces may have a cover of debris, which can exhibit *patterned ground.

altocumulus cloud. A type of cloud indicating some form of vertical motion at medium levels in the atmosphere. It includes a wide range of cloud origins from genuine convection to billow and orographic clouds where the atmosphere is essentially stable, but the uplift is forced by mountains. Altocumulus clouds generally occur as globular masses in bands across the sky.

altostratus cloud. A greyish cloud sheet normally composed of a mixture of ice crystals and water drops. It is distinguished from cirrostratus by lying at lower levels, being somewhat thicker, and not exhibiting halo phenomena. The sun may be seen through the thinner parts of the cloud. It is frequently followed by rain as the approach of a warm front is heralded by this cloud type.

aluminium silicates. There are three aluminium silicates with the composition Al_2SiO_5, the polymorphs andalusite, kyanite, and sillimanite. They are found in metamorphic rocks mostly of argillaceous composition. Each has a different yet closely related crystal structure and is stable over a different range of pressures and temperatures.

Andalusite is *orthorhombic and usually pink or white in colour. The variety *chiastolite* shows a regular arrangement of impurities in the form of a cross. Andalusite is characteristic of the low-pressure and high-temperature conditions associated with contact metamorphism around igneous intrusions.

Kyanite is triclinic and often blue-green to white in colour. It is stable at higher pressures than andalusite and is found in intermediate- to high-grade regionally metamorphosed rocks.

Sillimanite is orthorhombic, usually white in colour, and commonly occurs as acicular crystals, hence the alternative name *fibrolite*. It is stable at higher temperatures than kyanite or andalusite and is found in the highest grades of thermally and regionally metamorphosed rocks.

The orthorhombic aluminium silicate *mullite* has a composition $Al_6Si_2O_{13}$. It

is found in argillaceous xenoliths *(buchites)* in basic igneous rocks.

amber. Yellow translucent resin exuded by trees and often enclosing insects that have been trapped on the sticky surface prior to hardening.

amethyst. A purple variety of quartz. The colour is due to impurities of iron oxide. *See* silica minerals.

ammonite. One of the more advanced molluscs of the subclass *Ammonoidea, whose shells had extremely convoluted crinkled suture lines. They are known from the Permian, are valuable as Mesozoic zone fossils, and became extinct at the end of the Cretaceous Period.

Ammonoidea. An extinct subclass of marine molluscs of the class *Cephalopoda. Ammonoids had external shells, usually coiled in a plane spiral and divided by septa into chambers. The shells ranged from about 25 mm in diameter to over 2 metres in some species. The animal inhabited the terminal, and most recently formed, of these. The chambers were connected by a sometimes discontinuous calcareous tube known as a *siphuncle*. The septa met the inner wall of the shell at intersections called *suture lines*, and the character of these in fossil shells is used in taxonomic classification. The Ammonoidea had relatively complex suture lines compared with those of the *Nautiloidea; early ammonoids had angular folded suture lines (*see* goniatite) but in the later *ammonites the suture lines were highly convoluted and crinkled. Ammonoids probably evolved from the nautiloids and the earliest are known from rocks of Silurian age. They reached their peak of development in the Mesozoic, for which they are important *zone fossils, and became extinct at the end of this era.

amorphous. Having no regular atomic structure.

Amphibia. The first class of vertebrates to colonize land, evolving from crossopterygian fishes in the late Devonian. These fish had a bony skeleton that could provide support out of water; they also had lungs and their fleshy paired fins evolved into the more substantial limbs of the Amphibia. Amphibian eggs remain unprotected and must be laid in water, where the animals, too, spend their early life as tadpole larvae before undergoing metamorphosis into the terrestrial adults. The Amphibia were abundant in Carboniferous swamps, some reaching the size of modern crocodiles, but the class was in decline by the end of the Palaeozoic. Modern representatives include newts, salamanders, and frogs. Amphibians were the ancestors of the reptiles.

amphiboles. A group of rock-forming minerals that have $(Si,Al)O_4$ tetrahedra linked to form a double chain. *Pyroxenes are a similar group but with a single chain structure. The general amphibole formula is $X_{2\text{-}3}Y_5Z_8O_{22}(OH)_2$, where X = Ca, Na, K, Mg, or Fe^{2+}, Y = Mg, Fe^{2+}, Fe^{3+}, Al, Ti, or Mn, and Z = Si or Al. The hydroxyl ions may be replaced by F, Cl, or O.

Most amphiboles are monoclinic but anthophyllite and gedrite are *orthorhombic. Sub-groups are based on the dominant cation occupying the X position.

1. *anthophyllite-cummingtonite sub-group:*

anthophyllite $(Mg,Fe^{2+})_7(Si_8O_{22})(OH,F)_2$

gedrite $(Mg,Fe^{2+})_6Al((Si,Al)_8O_{22})(OH,F)_2$

cummingtonite $(Mg,Fe^{2+})_7(Si_8O_{22})(OH)_2$

grunerite $(Fe^{2+})_4(Fe^{2+},Mg)_3(Si_8O_{22})(OH)_2$

2. *hornblende sub-group:*

tremolite $Ca_2Mg_5(Si_8O_{22})(OH,F)_2$

actinolite $Ca_2(Mg,Fe^{2+})_5(Si_8O_{22})(OH,F)_2$

hornblende $NaCa_2(Mg,Fe^{2+},Fe^{3+},Al)_5((Si,Al)_8O_{22})(OH,F)_2$

edenite $NaCa_2(Mg,Fe^{2+})_5(Si_7AlO_{22})(OH,F)_2$
hastingsite $NaCa_2(Fe^{2+},Mg,Al,Fe^{3+})_5(Si_6Al_2O_{22})(OH,F)_2$
kaersutite $Ca_2(Na,K)(Mg,Fe^{2+},Fe^{3+})_4Ti(Si_6Al_2O_{22})(O,OH,F)_2$
3. *alkali amphibole sub-group:*
glaucophane $Na_2,Mg_3,Al_2(Si_8O_{22})(OH,F)_2$
riebeckite $Na_2,Fe_3^{2+}Fe_2^{3+}(Si_8O_{22})(OH,F)_2$
richterite $Na_2Ca(Mg,Fe^{2+},Mn,Fe^{3+},Al)_5(Si_8O_{22})(OH,F)_2$
katophorite $Na_2CaFe_4^{2+}(Fe^{3+},Al)(Si\text{-}AlO_{22})(OH,F)_2$
The angle between the prismatic cleavages of amphiboles is 124°, the corresponding angle for pyroxenes being 87°. Some amphiboles occur in fibrous forms; asbestos is a fibrous form of actinolite.
Members of the anthophyllite-cummingtonite sub-group together with tremolite, actinolite, and hornblende occur in metamorphic rocks. Hornblende is also common in igneous rocks. The alkali amphiboles occur in alkali igneous rocks with the exception of glaucophane, which is an index mineral of the glaucophane schist facies.

amphibolite. A metamorphic rock consisting predominantly of amphibole. *See also* metamorphic facies.

amphidromic system. A type of tide or tidal system in which the high water rotates around a central point (the *amphidromic point*). It is one consequence of the modifying influence that the earth's rotation has on a standing oscillation. The range of the tide is nil, or very small, at the amphidromic point itself but increases outwards from the point. The times of low and high water progress in an anticlockwise or clockwise direction around the amphidromic point. In the N hemisphere, high water rotates anticlockwise round the central point.

amygdale. A spheroidal or ellipsoidal *vesicle within a lava, filled with deuteric or secondary minerals often in a zonal arrangement. Typical amygdaloidal minerals include calcite, zeolites, and quartz.

anabatic wind. An upslope breeze often developing when mountain slopes are heated by the sun during calm conditions. As turbulence is greater during the day it is more often suppressed than the night-time equivalent, the *katabatic wind.

anafront. Any frontal surface at which the warm air is rising. As air cools on rising, condensation and precipitation are more extensive with this type of front than on a *katafront, where air is descending.

analcime (analcite). *See* feldspathoids.

analogues. Similar patterns of the surface atmospheric pressure field that occur at different times or different places. The basic assumption in analogue forecasting is that if two pressure situations are identical then the weather sequences that followed the first occasion will also follow the second. However, since analogues are never identical in all important features, only general trends can be deduced.

anatase. A brown to black tetragonal polymorph of TiO_2 found in vein deposits and pegmatites. *See* brookite, rutile.

andalusite. *See* aluminium silicates.

andesine. A variety of plagioclase *feldspar.

Andesite Line. A line that delimits those parts of the earth's surface that are of true oceanic structure as compared with true continental structure. The line can be drawn throughout the Pacific Ocean: on the ocean side of it are volcanic rocks that are entirely basic in character, but no in-situ volcanic rocks of the continental type. In the case of the W coast of North and South America, the Andesite Line runs parallel to and comparatively close to the coast.