Continents in Collision

Basil Booth

Mountains rise, and then they crumble away. Large segments of the earth's crust drift, seemingly aimlessly, about the face of the globe. Continents are in collision, and heave the beds of oceans many km above their original resting place. The ground breaks open and spews out molten rock; this becomes new land. It is upon such land that we now live.

Forty years ago a German meteorologist and explorer died on the wastes of the Greenland ice-cap. He was regarded as a crank because he had said that the continents had wandered about the face of the earth driven by unseen forces. Alfred Wegener, the proposer of this theory, was born in Berlin in 1880, the son of an evangelical preacher. He spent much of his academic life writing about meteorology and visited Greenland 3 times before he lost his life in 1930. His ideas were well in advance of his time; he was born, one might say, 30 years too soon. His theory was rejected and scoffed at, yet today we know that he was right.

The layman may not easily recognise that the rocks upon the face of the earth had a fiery beginning, but the simple fact is that they did. Since their formation over 5 000 million years ago they have undergone many changes, some have been remelted, some have been subjected to intense pressures and heat, while others have broken down to form the constituents of yet another rock. These processes have been going on since the formation of the earth; they are going on today and are part of a continuous recycling process.

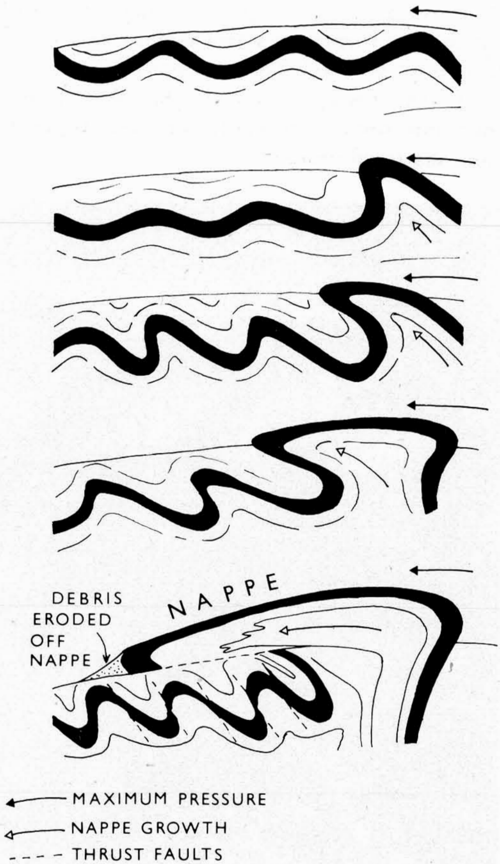
The study of these complex changes in the earth's crust make up the science of geology. The mechanism which builds mountain chains is known as orogenesis and it is by this process that continents increase in size. While we understand a great deal about the earth's internal and external processes there are many things of which we know little or nothing. It is upon such problems that earth scientists thrive; but there are difficulties here. The further we go back into the geological record the more difficult becomes interpretation. One of the reasons for this is that the oldest rocks are very often the ones which are the most altered. The earth scientist has then not only to unravel the processes which caused the formation of the rock, he has also to unravel its true nature by identifying all the factors which brought about its alteration: the type and amount of chemical addition and subtraction, the kind and degree of folding to which it has been subjected, the amount of compression and so on.

14 The Bernese Oberland, near Kandersteg, Switzerland. Overfolding of the rocks here has inverted the beds in the middle limb. Continued pressure would have sheared the middle limb and carried the upper limb forward as a nappe

We must ask ourselves questions like why fossiliferous limestones, for example, which were formed in warm shallow seas are now found several thousands of feet above sea level. The evidence of the rocks is beyond question, so what then is the driving force which has heaved them from the oceans and thrown them into sometimes highly contorted folds and raised them to form lofty frost-shattered peaks?

15 The Toggenburg from the Santis, Switzerland. The steeply dipping rocks are part of the lower limb of a huge fold whose upper part has been sheared off or eroded away

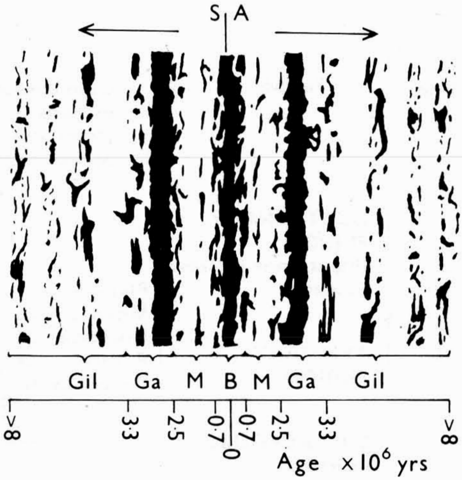
The answer lies in the new science of plate tectonics. Two continental plates, separated by a basin of deposition containing sediments eroded from the plates and also containing limestones and the fossiliferous remains of creatures that once lived in the seas bordering these continents, move slowly together. This squeezes the sediments out of the basin like putty in a vice. Because of the intense pressures involved, heat is generated and some of the sediments become chemically altered, or even melt and travel upwards from their original position to invade the overlying and adjacent rocks as igneous intrusions. If the pressure is directed from one mobile plate towards a relatively static one then large folds may develop, overlap one another and be pushed on to the static plate.



Diag. A Diagrammatic development of a nappe

With continued pressure the folds become broken off from their roots and travel great distances in the growing mountain pile as nappes. While this is going on, erosion is already biting away at the surface of the young pile, and sediments may be eroded off the top of the advancing nappe, deposited in front of it and finally overidden by the nappe, which itself may overide or be overidden by another nappe. This is obviously a simplification of the whole story, but it is due to such a process that mountains like the Alps were formed.

What then set the Wegenerian train in motion, and brought about the revolution in the earth sciences that created the unifying theory that we are presented with today? To answer that question we must go back to the 1950s when there was a burst of interest in oceanography. Hess (1962) and Dietz (1961) proposed a combined hypothesis that the ocean basins evolved by means of 'sea-floor spreading' from mid-ocean ridges, saying that new rock was created at these ridges by volcanism and moved progressively away from the ridge as fresh rock was brought up from the earth's mantle.



Diag. B Magnetic anomaly strips map. SA: Spreading axis, B: Brunhes normal, M: Matuyama reversal, Ga: Gauss normal, Gil: Gilbert reversal. Black: normal magnetic anomaly, White: reversed magnetic anomaly

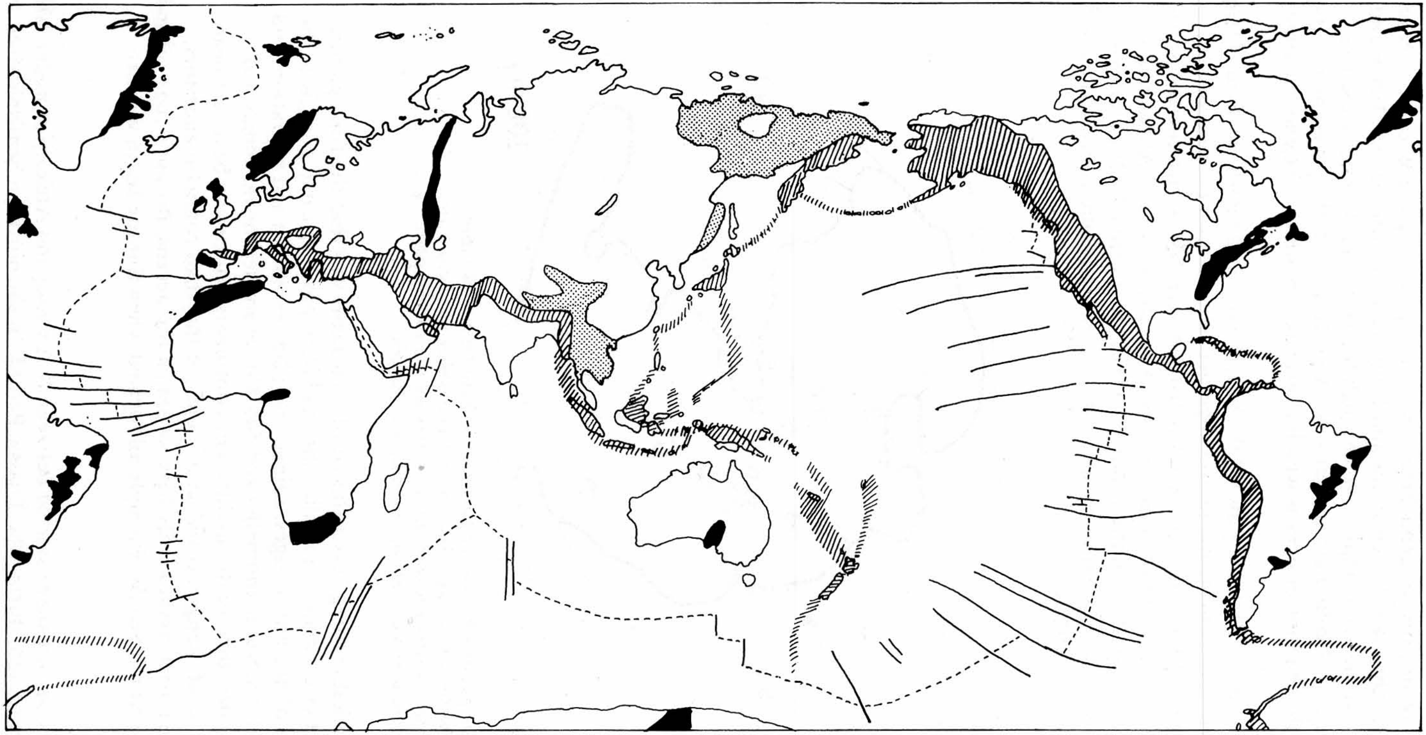
The hypothesis was put to the test when Vine and Matthews (1963) found that these volcanic rocks had been imprinted with the earth's magnetism prevailing at their time of cooling. These magnetic anomalies as they are called, showed reversals in polarity caused by the reversals of the earth's magnetic field through time. The pattern of these oceanic magnetic anomaly-strips was found to lie symmetrically either side of the mid-oceanic ridges. Heirtzler (1968) was able to assign a time scale to these anomaly strips for the sequence of earth polarity events and thereby give ages for the formation of the new rock.

At the same time as these developments were taking place, a world-wide standardised seismographic network was being installed in 1962. This was to give valuable information about the focal depths and positions of large numbers of earthquakes throughout the world. The quakes were found to occur along linear belts following mid-ocean ridges and also along inclined zones dipping down from deep ocean trenches below adjacent land masses or island arcs.

It was found that the mid-ocean ridges, transform faults and the ocean trenches/island arc/continental masses systems were all linked by a world wide network of seismisity zones which divided the globe up into 6 major plates and many minor ones. New oceanic crust was created at the mid-oceanic ridges, or spreading axes; these were themselves sheared by transform faults; and the crust destroyed at the oceanic trenches where it dived beneath an adjacent plate along an inclined plane marked by seismic zones. The concept of plate tectonics was born.

Eras	Periods		Estimated age in millions of years (from base of period) to present	Plate movements
CAINOZOIC ERA	QUATERNARY PERIOD (Pleistocene & Recent Epochs)		c2	Last glaciation
	TERTIARY PERIOD	Pliocene	c7	
		Miocene	26	
		Oligocene	38	
		Eocene	54	Europe and Greenland part. Africa makes contact with Asia Pre-Gulf of Aden closes
		Palaeocene	65	
MESOZOIC ERA	CRETACEOUS PERIOD		136	Arm of mid-Atlantic extends into Pacific
	JURASSIC PERIOD		195	Break-up of Pangea starts Pangea formed
	TRIASSIC PERIOD		225	Siberia collides with Europe Africa, S. America collided with Europe
PALAEOZOIC ERA	PERMIAN PERIOD		280	
	CARBONIFEROUS PERIOD		345	America's collided with Europe to form Caledonides of Norway and Scotland, etc.
	DEVONIAN PERIOD		395	N. America collides with Europe Closing sea forms Newfoundland
	SILURIAN PERIOD		440	
	ORDOVICIAN PERIOD		c500	Series of trenches formed down east coast of America's
	CAMBRIAN PERIOD		c570	
PRE-CAMBRIAN ERAS			up to 5,000?	

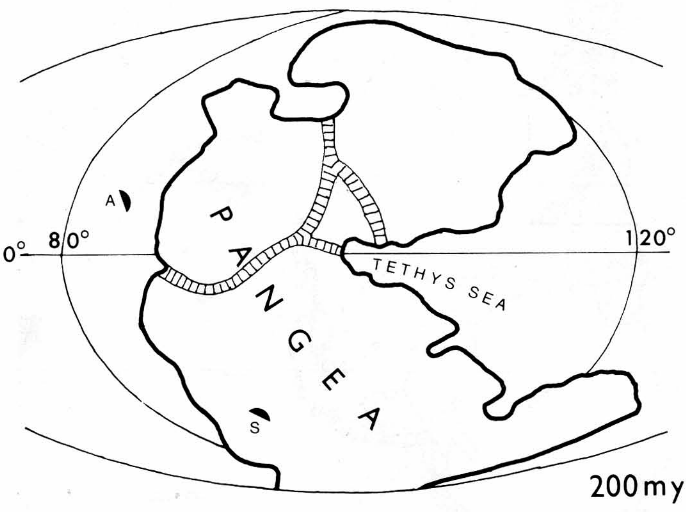
Diag. C Abridged geological time scale showing some more important plate movements



Diag. D World map of orogenic belts. Black: Palaeozoic and older orogenic belts, Shaded: Early mid-Mesozoic orogenic belts, Cross shading: Mesozoic-Cainozoic orogenic belts (including island arc systems), Dotted line: Mid-Ocean spreading ridges, Solid lines: Transform faults

In global terms, the orogenic belts have developed along the W coast of N and S America, through the Aleutians and Kamchatka, down through Japan and into the Indonesian complex, up through Sumatra and Burma, across the Himalaya and Middle East and into the Alps. In general the development took place at the margins of oceans which contracted in Mesozoic-Cenozoic times.

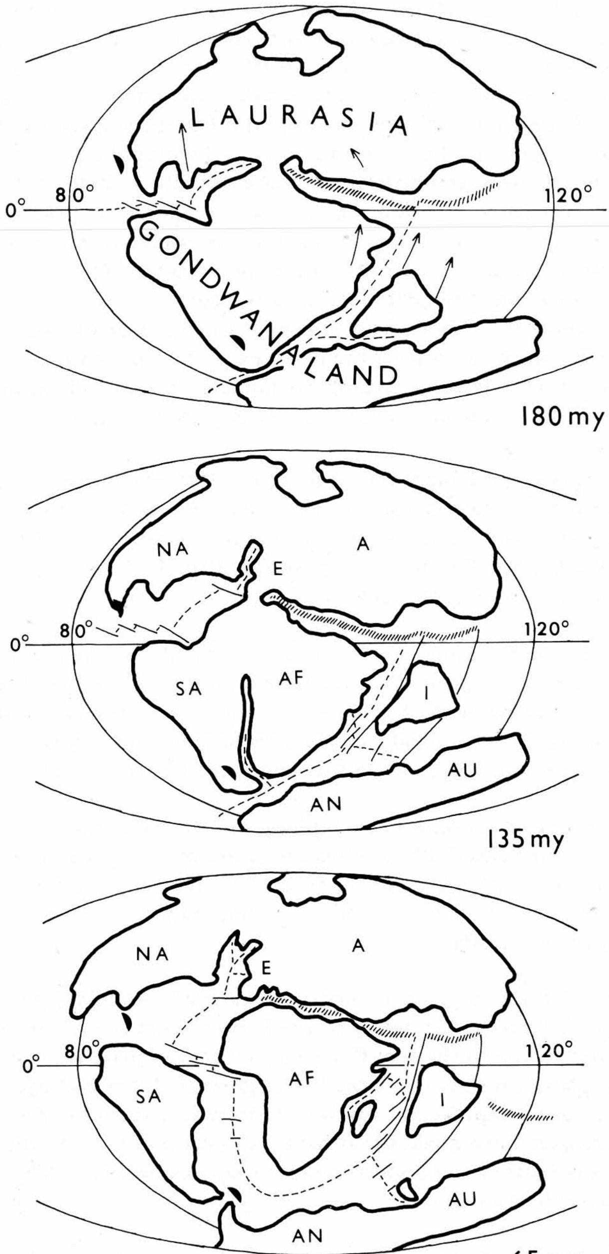
During the mid-1960s Sir Edward Bullard, Everett and Smith set about fitting the present day continental masses together. With certain exceptions they accomplished their task. S America fitted S Africa, NW Africa fitted eastern N America, and N Canada fitted E Asia. Australia, India and Antarctica all fitted neatly together on the E side of Africa. This formed a large super-continent named Pangea, meaning 'all lands', a term originally conceived by Alfred Wegener in the 1920s.



Diag. E The Supercontinent of Pangea may have looked like this some 200 million years ago. Solid arcs: (A) Antilles, (S) Scotia arc, Shaded areas: position of ancient mountain belts outlining plate collision boundaries during the formation of Pangea

The remarkable thing about this fit of continents was that the final picture explained away many anomalies that had been puzzling earth scientists: the problems of ancient ice-ages, animal and plant evolution and migration, and geological structural anomalies and fits. For example, the mammals had evolved quite differently on different continents, the brown bear, ant bear, elephant, wolf, kangaroo and so on, and yet they had common ancestors. Those ancestors could hardly have swum all the oceans. Britain's coal, oil and gas of the North Sea for example all formed when Europe lay in warmer latitudes.

The break-up of Pangea started between N America and Africa just under 200 million years ago, during the Triassic Period. In the northern hemisphere N



Diag. F(1)(2)(3) The break-up of Pangea. Showing (1a) the development of spreading axes and the separation of Laurasia and Gondwanaland, (2b) the separation of the continents as we know them today—NA: North America, SA: South America, E: Europe, A: Asia, AF: Africa, I: India, AN: Antartica, AU: Australia, (3c) the spreading axes increase in number and diversify, while the plates drift towards their final position. Island arc systems form, north of India and Australia, which later collapse and fold to form orogenic belts of the Alpine-Himalayan chain

America and S America opened, and the split wedged Africa away. At the same time Antarctica broke away from the African continent, carrying India and Australia with it. The first crack to develop, the mid-Atlantic ridge, pushed Spain and France away from N America and divided Canada from England, but not until 60 million years ago did Europe and Greenland finally part company. Later still, between them, Iceland emerged on the mid-Atlantic ridge, India broke away and drifted NE and eventually collided with Asia to throw up the Himalaya. The mid-ocean ridge extended round the Cape and into the Indian Ocean and very soon separated Australia from Antarctica. An offshoot from the mid-oceanic ridge in the Indian Ocean broke Madagascar away from Africa, and a rift extended into the continent there, but did not get very far. Another offshoot from this mid-oceanic ridge extended up between Africa and Asia creating the Red Sea, and even today it is slowly closing the Gulf of Oman and causing earthquakes in Iran and Turkey. It was this N motion that threw up the folds of the Zagros mountains.

During the break-up of Pangea the large Tethys sea, which existed to the E of the supercontinent, slowly began to close. Sixty-five million years ago Africa had made contact with Asia, leaving a thin arm of Tethys as the pre-Mediterranean and pre-Gulf of Oman. The expansion of the Red Sea ridge closed the gap during the last 60 million years.

An arm of the S mid-Atlantic oceanic ridge extended into the Pacific area 135 million years ago. Very little is known about this, but it may have been important in the opening of the E Pacific Rise, another mid-oceanic ridge, which is slowly pushing the Nazca and Cocos plates beneath the American plate to cause earthquakes and volcanoes in the Andes and Central America.

The importance of mountains in elucidating the complexities of plate tectonics cannot be overemphasised. Plate collisions create mountains and therefore mountain chains should tell us where there have been ancient plate collisions. Bearing this in mind let us look briefly at young mountains that are still in the process of formation today.

In the Azores, 2 plates meet in a constructional plate boundary where new ocean floor is generated. Extending to the E away from the Azores is a long transform fault, while to the S of Portugal the African plate is pressing against the Eurasian plate. Interaction of the forces generated in S Portugal resulted in the disastrous earthquake in Lisbon in 1755 which destroyed the city. Even recently there have been quakes that have given cause for alarm; the fault responsible was located and underwater television cameras found displacements of several feet along it.

Even the floor of the Mediterranean is still on the move. In response to the intense pressures generated between the N moving African plate against the Eurasian plate, the floor of this sea is going down. In the E however, it is rising and a big volcanic island exploded 34 centuries ago giving rise to the legend of Atlantis. In Cyprus there is further evidence for the rise of the floor of the Mediterranean. The ocean floor has been buckled into the air by pressure between the plates, the rocks there are found to be mantle material which is rich in iron and magnesium and very dense, material which is normally found at a depth of 8 miles or so. Cyprus is probably the forerunner of another great mountain chain slowly rearing its head.

These, however, are young mountain building movements. Perhaps by looking at older mountains we can tell how the supercontinent of Pangea was formed. Across the Atlantic Ocean, in Newfoundland, mantle rocks are again encountered. They occur under very similar conditions to those in Cyprus, and again they are rich in iron and magnesium and contain, like the Cyprus rocks, vast quantities of copper. These mantle rocks, which have come from the bottom of the earth's crust, occur as sheets of lava which filled cracks in the crust when the ocean floor was growing. Newfoundland is some 400 million years old, much older than Cyprus, and was formed by the closing of a small sea. Here then is some of the gathering evidence for the formation of ancient mountains by ancient seas.

Where there is a prominent chain of mountains over 200 million years old running across a continent it is now believed by many geologists that they were formed by the collision of even older continental masses. For instance, the Urals which stretch from S to N across Russia were produced when Siberia collided with Europe about 250 million years ago. Running along the axis of the Urals are a whole series of ocean floor rocks just like those in Cyprus and Newfoundland. These ocean floor rocks are arranged in very distinct linear zones and mark the spot where the collision occurred.

If we trace out the belt of ocean floor rocks for other areas around the world we find lines extending down Greenland, Norway and Scotland, through Newfoundland and into the Caribbean. A belt also stretches out from S

18 Huzi volcano, Japan, (Synonyms: Huzi-san, Fuji, Fuji-san). Situated on the overhanging plate boundary on the Japanese Island Arc system and adjacent to the deep sea trench where the down-going plate from the E is destroyed. Many volcanoes mark such destructional plate boundaries. Photo: I. Yoshizawa

Europe to join the Appalachians near New York. Taking these lines to represent the borders of ancient continents and ancient oceans, we begin to get some idea of what the pre-Pangean continental distribution must have looked like.

Oceans existed between the former Europe and N America; Africa and S America were separated by an even wider ocean. Along the coast of N America are a whose series of limestones in which are found tropical fossils which must have been formed near the equator. Yet Africa must have been near the S pole at that time, as a whole series of glacial deposits are found in the Sahara. So, the ocean at that time must have been very wide.

About 500 million years ago a series of trenches and island arcs started to form down the E coast of America. N America started moving towards Europe and collided with Europe about 350 million years ago to form the Caledonian mountains of Norway and Scotland, and the N Appalachian mountains in eastern N America. Later, Africa and S America started converging and about 250 million years ago collided with Europe to throw up the S Appalachians and the mountains of S Europe. All the time this was going on, Siberia had been moving in towards Europe and eventually collided with it about 250 million years ago to throw up the Ural mountains. So we now know how the older mountains were formed and why they possess such strong linear belts, and why they contain so much material raised up from the oceans. Continents have probably been on the move for at least 2000 million years of the earth's history.

Summarising events, we can say that in pre-Pangean times 500 million years ago, Africa and S America were upside down, and the Sahara was near the S pole. Antarctica, India and Australia were joined to Africa, and remained so until they broke away from Pangea about 200 million years ago. Asia had already broken away from them and N America and Europe were close together in the S tropics while Scotland was across the former Atlantic ocean next to Greenland.

As the continents drifted together, ocean floor was destroyed and volcanoes created along the ocean edge that produced Snowdonia and the volcanic rocks of the Lake District.

When N America and Europe collided 350 million years ago, they trapped a mass of ocean mud between them, and Britain was created. The mountains of Scotland and Wales and the N of Ireland were part of a long chain that ran from Norway right across to N America. In Scotland the old continents have welded themselves together along a line from Ayr to Dunbar. After collision the earth's crust cracked along a new line and the plates moved again, this time along a transform fault like that of San Andreas. The fault line is still there and is occupied by Loch Ness and the Great Glen. Even today earthquakes are recorded from this region.

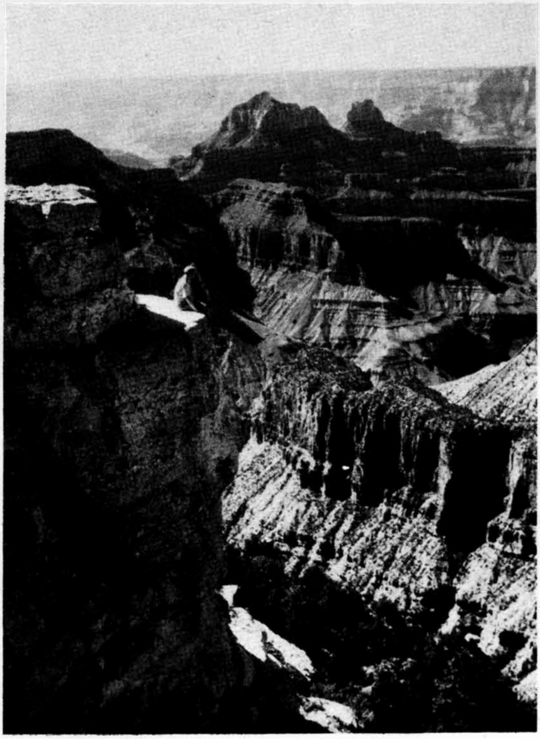
17 Great Glen, Scotland. A transform megafault which opened after North America collided with Europe 400 million years ago. The fault is still active today, though on a very much reduced scale. Photo: Aerofilms Ltd.

Life had only recently migrated out of the sea, Britain lay at this time in the tropics and swampy forests grew which later turned into coal. At this stage in development S England was not yet attached to the rest of the country, but is thought to have been somewhere near to France, S Germany and Africa which were at that time joined together. As Pangea formed, with England right in the middle of it, the mountains of S Wales and the Pennines were heaved up and the coal was trapped and buried around them. The same applied to N Ireland. There were no islands then, for they lay in the centre of a super-continent and for a long time they were a desert like the Sahara; in fact the evidence for the desert conditions of these times is seen in the Permo-Triassic sand and salt deposits of N England.

The last upheaval was after the break-up of Pangea when Italy struck Europe like a battering ram and threw up the Alps. France shielded Britain during this event, but some crumpling produced the Downs of SE England while in the Isle of Wight the layers of rock are vertical. The London region was buckled down and the Weald of Kent and Sussex was raised as a great dome of chalk, a tail-end of the Alps, now eroded by the elements.

The greatest scouring of the landscape occurred during the last million years or so, when the Arctic ocean cooled as a result of being hemmed in by N moving continents. Glaciers swept S several times, carving U-shaped valleys and depositing glacial debris over the countryside during their retreat. It was this last period of frost shattering that gave us the mountains that we know today.

Mountains are generally regarded as topographically high areas, often with snow covered peaks. The geological definition puts closer constraints upon the use of the term mountain. In the geological sense a mountain is not just an elevated area, it is also underlain by strongly folded and faulted rocks, or indeed by large igneous masses such as granite batholiths or piles of ancient volcanic tuffs and lavas. If on the other hand the area is underlain by sedimentary rocks which are more or less horizontal or gently dipping, they should not be called mountains.



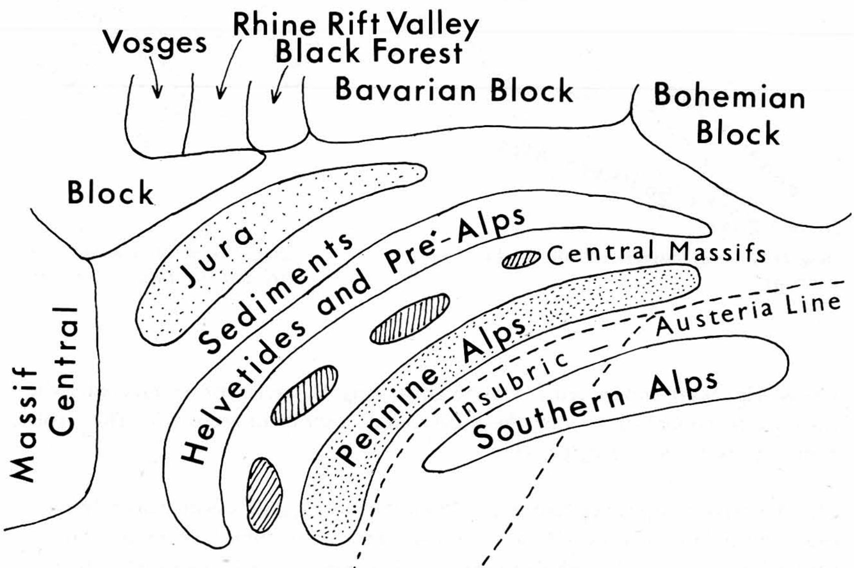
18 Grand Canyon, U.S.A. Although resembling a mountain area, it is certainly not one. Here, horizontal sedimentary rocks are deeply cut by river action but are not underlain by strongly folded and faulted rocks, or by igneous masses as true mountains demand. Photo: Tom Connor

For example; the Colorado Plateau is intricately cut by stream canyons thousands of feet deep, and although the walls are in places vertical and high rocky peaks jut up from within the canyon area, it is not considered by geologists to be a mountain area. This may seem strange, especially when one considers that the Appalachians and Urals have a smaller relief than the Colorado Plateau area. But the former two are underlain by highly folded and partly metamorphosed rocks and are therefore considered mountains in the true sense of the word.

The Alps without doubt are the best known complex mountain chain in the world; many earth scientists have spent years trying to unravel its mysteries and the Alps have often been taken as a prototype of an orogenic system. This is perhaps unwarranted, as all mountain chains have their own individual characteristics. Nevertheless this has often been the case, and the geotectonics of mountain chains far removed from the Alps have been based upon the geotectonics of the Alpine region.

However, the Alps do have some interesting features which merit discussion, particularly concerning their much disputed genesis. European workers have from time to time propounded conflicting theories for the formation of the Alps, but in general they all agree that these mountains were formed by the buckling and thrusting up of sediments from the pre-Mediterranean sea, the ancient Tethys.

The Alps consist of a curved chain of longitudinal zones which are nearly parallel. To the N lie the Jura mountains. These are separated from the Helvetides (the High Calcareous Alps) and Préalps to the S by the sediments of the Swiss Plateau. South of this is a chain of Central Massifs (the pre-Mezozoic crystalline wedges) followed by the Pennine Alps. Separating the Pennine Alps from the S Alps is the Insubric-Austeria line, a tectonic fault zone.

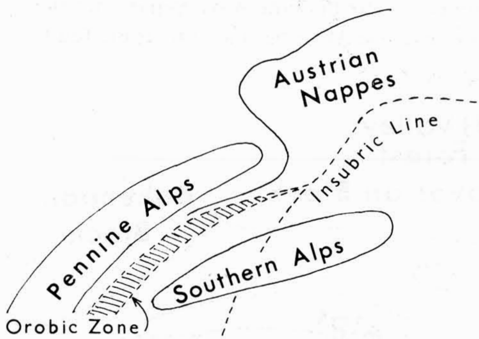


Diag. G General diagram of the Alpine structural zones

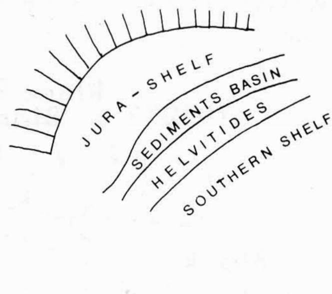
The S Alps consist of the Lombardy and Tyrolese Alps. The Lombardy Alps are separated from the Pennine Alps, and the Pennine Alps from the Helvetides by geanticlines, great areas of land folded into gentle arches. The differing sedimentary characters of the Pennines and Helvetides is reflected in their individual structural relations.

It was presumed that the NE to SW trends were parallel to the Carboniferous basin in the W (part of Tethys), the Briançon zone, and that they represent a posthumous Hercynian alignment. The Permian was deposited in a NE–SW basin which appears to cut through a later pattern, also the Triassic limestones of the Austrian geosyncline which lay to the E were nowhere near parallel to the present trend. The present Alpine trend was initiated with the development of the Liassic trough of the Pennines. The preliminary conclusion that the Hercynian trend interferes with the Alpine direction to cause E–W zoning and strong fold plunges is soon reached.

To emphasise the individuality of the Alps the following description of their formation is relevant. During upper Cretaceous times the deep Pennine geosyncline was narrowed by lateral pressure by the African plate, and flow structures made possible by intrusions of magma and melting of the uplifting sediments. Secondary ridges and basins were compressed to form a single basin which filled up with detritus derived from its N end, which was at that time rising. Sediments were also presented from the Orobic zone and also from the Austrian sheets in the E.



Diag. H General diagram of the Orobic zone of the Alps



Diag. I General diagram of the Helvitides in post-Eocene times

The S Alps were separated from the advancing Austrian thrust sheets by the Insubric tectonic fault zone; these formed as a series of steps with the Orobic zone representing the upper one.

The Austrian nappes represent the thick Permo-Triassic cover whose front sheared the Jurassic and Cretaceous sediments from their basements. The thrust faults originally cut deep into the basement, as proved by the thick slices of crystalline basement included in the sheared sedimentary rocks. The thrust faults also cut obliquely through the present E–W trend.

As the jaws of the Tethys sea closed, the Pennine structures in the W slipped along the then existing continental shelf and curled up against it. This in turn arched up to form the Central Massif of the Gotthard and Mont Blanc while the Préalps zone was pushed over and on to the Helvetic zone. Meanwhile, geanticlinal ridges which arose were eroded down and their sediments deposited in deep troughs created by these massive earth movements. During post-

19 The Matterhorn Switzerland. The main part of this peak is composed of part of the upper limb of a huge fold which was sheared off from its roots to the S, and carried to the N as a nappe. Photo: AC collection

20 Mount Aspiring, New Zealand. Similar in aspect to the Matterhorn, this peak is the result of erosion and is not formed from a nappe. Photo: New Zealand Government Office

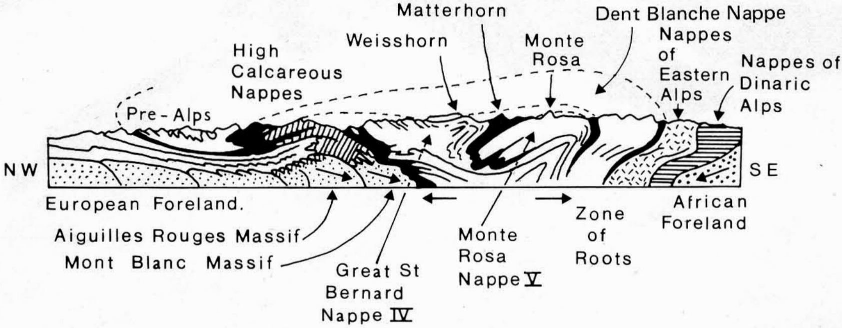
Eocene times the Helvetides and Préalps were sheared off from their basement, while N of the uplifting S shelf a deep trough was formed bounded on the N by a welt (shallow shelf sea).

Thrust faults developed in the sediments of this trough and the sediments eventually were thrust over the N welt and slid down its N slope after the welt itself had become uplifted to form the external massifs. The Préalps were carried part of the way to the N on the top of the N moving Helvetides.

Compression decreased towards the W, and the Préalps grade into thrust structures W of Geneva. The external massifs which were pushing upwards caused these thrust structures to reappear as folds overiding one another and tumbling down into a marginal trough which was filling up with coarse sediments supplied by the fronts of the advancing folds. Contemporaneously, the Pennine and S Alps rose even higher, and the Cretaceous and Paleogene cover of the Pennines slid to the N with the Helvetides and Préalps and became involved in their folds and nappes.

The elevation of the Orobic zone by lateral compression from the S accentuated the upper steps which acted as buttresses against which lower steps faulted and folded. Finally the upper steps slid S over the lower steps and the rising E Dinaric Alps. The shearing off which occurred took place along many horizontal planes which primarily divided the sedimentary sequence into individual sheets. These advanced one above the other and often carried forward an upper sheet; for example the Helvetian nappes. Each structurally formed basin played its own particular role in the diastrophic picture during its own phase of compression.

Orogenism began in the E and S and reached its maximum in the centre and progressed to the N. It appears that the central unit, the Pennine geosyncline, with its initial and syntectonic magmatic phases contains, if not the mechanical force, the capacity to unleash the diastrophism. Compression deep in its basement, when the sedimentation of its youngest deposits was still in progress and the geosyncline was still rapidly subsiding, started the Austrian nappes.



Diag. J Section across the most complex part of the Alps

21 Mount Everest, Himalaya. Part of the great mountain chain which arose as the result of the collision of the subcontinent of India with Asia, less then 60 million years ago. Photo: AC collection

While the breakup of the supercontinent of Pangea caused the Tethys sea to close from W to E, the evidence of the Alpine deposits seems to indicate that orogenesis began in the E and spread towards the W. Perhaps because of the greater width of sediments in the trough, the effect of the sea closing initiated folding in its E limb first. As the movement of the closure of Tethys is considered to have been scissor-like then the E plate margins would have closed relatively faster than the W margins. In fact the role of Tethys in the formation of the Alpine mountain chain is of paramount importance, as is the formation of the N–S spreading plate margins in the W of Pangea and the NE–SW spreading plate margins in the S of Pangea. It was these global movements that initiated the breakup of the supercontinent and caused the Tethys sea to close progressively as they started their movement towards their present positions.

Assuming the plates continue to move along their present paths, it is possible to prognosticate on the future. After the next glacial period in the N hemisphere the widening of the Atlantic will create a collision margin between Africa and Europe with some degree of folding, probably on a small scale. The Portuguese–Spanish peninsular could break away from Europe and drift

NW towards the S of Britain, to cause earthquakes and volcanic eruptions in the S Irish sea. The E coast of England will continue to subside, eventually drowning the London basin. N America will probably sever from S America near the Caribbean while Australia will drift N to collide with New Guinea. A large fragment of E Africa could be split off by progressive widening of the Rift Valley, and the widening Red Sea will become open to the Mediterranean.

It is doubtful if man will ever see the results of this prognosis, perhaps a new hypothesis will be put forward to replace the present theory although at the moment this seems unlikely. When Wegener said that the continents had drifted about the face of the earth he could not have foreseen the revolution in the earth sciences his theory would bring about.

GLOSSARY

Tectonic. Dealing with the structure and structural elements of the rock.

Magnetic Anomaly Periodically the earth reverses its magnetic field. Molten rock, or magma, which finds its way to the surface of the earth has particles of iron ore in it magnetised in the same direction as that of the earth's magnetic field prevailing at the time of the event. When the field N–S is reversed it is called an anomaly.

Transform Fault A displacement of the rock strata, in which the rocks instead of moving more or less vertically, slide past each other on the horizontal on what is called a transform fault.

Island Arc An arcuate distribution of oceanic islands, found in the W Pacific ocean, where one side of the arc is bounded by a deep ocean trench, the arc itself having volcanoes which are more often than not active.

Mantle The earth is divided into concentric zones of rock which differ in density. It is this which gives us the different speeds of earthquake waves within the earth. The outermost shell, beneath the skin, crust, or lithosphere is called the mantle; this extends inwards to the core.

Igneous Pertaining to fire. Rocks formed by passing through the molten stage.

Batholith A large igneous rock body. Formed at depth. Very large and having fairly steeply plunging sides. Many granite bodies are batholiths; for example the SW England granites of Devon and Cornwall.

Metamorphosed Meaning altered. Rocks which have been altered in structure and chemistry by the application of heat and/or pressure.

Hercynian A mountain building phase which occurred in the Permian period. This term should be reserved for Europe only; sensu stricto.

Geosyncline A deep trough of sedimentation found at the border of a continent and into which debris eroded from the continent is being deposited. The trough is situated in an unstable zone and is likely to be closed by compression and the sediments in it folded.

Diastrophic A general term for all types and modes of deformation in the earth's crust.

Syntectonic At the same time as tectonic events.