set extending towards the 5' end of the genome. Each appears to be translated independently to produce a single protein which corresponds in size to the unique 5' terminal sequences not present in the next smallest RNA (reviewed in ref. 1).

M. Lai (University of Southern California, Los Angeles) reported T1 oligonucleotide mapping data showing that, in addition to the common 3' sequences, a common 5'-terminal leader sequence is present on each of the mRNAs, derived from a 5'-terminal sequence present only once in the genome RNA which must become translocated onto the mRNAs during their synthesis or generated by a splicing mechanism. Two alternative approaches have confirmed the existence of leader sequences on coronavirus mRNAs. Hybridizing cDNA molecules (W. Spaan, University of Utrecht; H. Delius, EMBL, Heidelberg) transcribed from homogeneous genomic mRNA (T1 to genome RNA and examining the hybrids by electron microscopy after cytochrome c spreading shows that the bulk of the cDNA hybridizes to the 3'-terminal region of the genome. However, about 50 nucleotides from the 5' terminus of genome RNA also hybridizes to the cDNA, resulting in large looped structures about 19 kb long. Direct sequence analysis of mRNA 7 and the corresponding region of the genome has also been carried out (J. Armstrong, EMBL; M. Skinner, University of Würzburg; Spaan).

This work confirms the existence of a 'fusion sequence' since the nucleotides sequence of the 5' region of mRNA 7 diverged from the corresponding genome region upstream from the N-gene initiation codon. Fusion of leader and body sequences occurs within the sequence 5' AAUCUAACUAAC 3', which does not include the consensus established for splice junctions in viral and cellular mRNAs. Conventional splicing also seems to be ruled out since murine coronaviruses replicate in nucleated cells, and transcriptional mapping shows that the target size of each mRNA corresponds to its physical size. The template for mRNA synthesis is a single genome-length negative-stranded RNA molecule (Lai), so each mRNA must be individually transcribed at its own initiation point on the negative-strand template.

Two possible mechanisms by which leader sequences could become fused to mRNA body sequences during transcription were considered at the meeting. The first involves bringing together non-contiguous sequences on the negative-strand RNA template by secondary structure alterations which lead to looping or folding of the molecule. The polymerase could read the leader sequence then jump across a postulated gap in the template, joining the leader to mRNA body sequences in the process. Such a jumping mechanism, which requires ribonucleoprotein structure to bring together non-contiguous sequences, may be involved in the generation of defective interfering RNAs during influenza virus transcription. The second mechanism involves reinitiation of transcription near the start of each gene on the template; the leader RNA sequence remains attached to the polymerase after its own synthesis and primes transcription at six different regions along the template. This mechanism has recently been invoked to explain mRNA synthesis from overlapping genes in a negative-stranded bunyavirus. Although data are not yet available for murine coronavirus, Boursnell and Brown have found two regions of homology on the IBV genome which might be the primer-attachment points.

Lai presented evidence in favour of the second mechanism. Only full-length double-stranded replicative-form molecules were found in infected cells after ribonuclease treatment. If the first mechanism were correct, the second would be expected to be generated. Also, only one species of replicative intermediate, migrating faster than genome RNA, was found by gel electrophoresis. This species was 40-60 per cent resistant to ribonuclease, and its structure suggested six single-stranded tails on each full-length template RNA.

The nature of the RNA-dependent RNA polymerase responsible for these events is still unclear. The current hypothesis would favour separate polymerase activities for the synthesis of negative and positive strands. Considerable further work on these enzymes is needed to establish the events involved in the unique RNA synthetic mechanism induced by coronavirus infection.

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News and Views

Earth science

Suspect terranes

from Peter J. Smith

AN unexpected revelation of the past decade or so in the field of global tectonics, but one rather slow to penetrate the consciousness of the wider geological community, is the degree to which continental drift can be a messy process. The simple view of the 'Wegenerian' drift of the past 200 million years is one of large more-or-less recognizable landmasses moving slowly across the Earth's surface in the context of spreading ocean floors and a lithosphere divided into a number of discrete plates. Such landmasses may be in the process of splitting apart, may have their outlines modified slightly by the offshore deposition of sediments, may collide and thus become severely distorted along their leading edges, may stretch and contract a little as they find themselves moving around an Earth of variable curvature, and may — although this is more dubious — grow slowly and steadily by accretion around their edges; but since the breakup of Pangaea they have, by and large, retained their original shapes and sizes. This turns out to be an oversimplification, and nowhere more so than in relation to western North America.

The North American continent that split away from Eurasia all those millions of years ago was 20-30 per cent smaller than the North America of today, but the subsequent growth took place not slowly by accretion around the edges but rapidly by the addition of lungs chiefly to one, the western, edge. A 500-km or so strip of the Pacific coast from Alaska to San Francisco, a rather narrower strip running south into Mexico and almost the whole of Alaska itself comprise a mosaic of 'suspect terranes' that were grafted onto the original stable craton of North America in ones and twos at various times between 200 and 500 Myr ago.

These suspect terranes, of which about a hundred have been identified, range in size from hundreds to tens of thousands of square kilometres. Most are apparently of oceanic origin — islands, plateaus, ridges and arcs — although a few are continental slivers. Some were identified, or at least regarded as 'suspect', even before continental drift became widely accepted, largely because they were found to have palaeontologies quite uncharacteristic of the region and quite different from those of adjacent terranes. Subsequent geological studies have confirmed the extent to which adjacent terranes are stratigraphically unrelated. More recently, palaeomagnetic studies have revealed that many of the terranes have not only come from up to thousands of kilometres to the south and west but have been rotated through up to 70°, before, during or since accretion. Some apparently joined North America individually; others amalgamated before reaching their current resting place; and still others have, since joining, split and separated from each other. Their status in plate tectonic terms is uncertain. Some of the larger terranes appear to be genuine 'microplates', comprising segments of the complete lithosphere down to the asthenosphere; some of the smaller ones may be comparatively thin blocks that have become decoupled from the lower lithosphere.

As the laborious task of defining,
Describing and locating the original positions of the individual suspect terranes continues, thoughts turn to the circumstances in which the terranes met their host. Much of the Mesozoic, the western margin of North America was a convergent boundary; and some rock formations in the region have even been recognized as subduction-related features. It is now clear from terrane studies, however, that during this period western North America grew much more rapidly than it could possibly have done simply by the scraping off of sediments from a subducting ocean floor and by the volcanism associated with a subduction zone. The ocean-floor spreading towards the North American craton during the Mesozoic evidently carried with it fragments of such buoyancy that they failed to subduct along with the bulk of the ocean floor and instead added themselves to the margin of the continent.

That being so, those fragments behaved very similarly to India, whose collision with, and failure to subduct beneath, the Asian mainland is held to be responsible for the upthrust of the Himalayas. The Pacific terranes may have been oceanic rather than continental and were certainly individually much smaller than India, but their fate was not so dissimilar, which is why Ben-Avraham et al. (Science 213, 47; 1981) suggested that suspect terranes may play an important part in mountain building. For example, the Laramide orogeny of 80-40 Myr ago, which gave rise to the western American Cordillera (the Rockies, Colorado Plateau and so on), has long been a puzzle insofar as it has proved difficult to account for such intense deformation over so wide a band on the basis of subduction alone. Just as India was essential to the formation of the Himalayas, so might suspect terranes have been necessary in the formation of the Cordillera.

The philosophical implication of this proposal is that there may not, after all, be two distinct types of orogeny (Andean and Himalayan) but only one. By that reasoning, Andean-style mountain building differs from the Himalayan variety only by being at a different stage of evolution. The former, involving chiefly smallish oceanic fragments, this occurs before and/or after subduction draws in a larger continent to institute the latter. Or to put it in terms of a concrete example, when India has been transferred completely to the Asian plate during the current Himalayan-style phase of orogeny, it will appear as if it were never on the Australian plate in the first place. All that will remain is an Andean situation in which a huge mountain range appears to have resulted from a subducting oceanic plate close by.

But that raises important questions about the Andes themselves. The practical implication of the Ben-Avraham hypothesis is that buoyant oceanic fragments are playing an essential part in the formation of the Andes, a range no less difficult to explain on the basis of subduction alone than was the Cordillera. The difficulty is, however, that apparently no suspect terranes have yet been found in the Andes. If they are discovered later, all will be well for Ben-Avraham et al. If they are not, that may be the end to the unitary theory of orogeny. It would then also be inappropriate to refer to mountain-building with oceanic fragments as Andean; Cordilleran-style and Andean-style orogenies would be distinct.

For the time being nothing more can be said about that because the Andes are but poorly understood. Meanwhile, however, it is pertinent to enquire whether there are other regions in the world in which the circumstances are more clearly comparable than those in the South Pacific to the circumstances presumed to have obtained off western North America during the Jurassic-Cretaceous. Silver and Smith (Geology 11, 198; 1983) made just such an enquiry and now claim to have identified just such a region, in south-east Asia. The accompanying map, used by Silver and Smith themselves, shows the chief terranes of western North America on the right and the current tectonic setting of the Indo-Pacific collision zone on the left (at the same scale but rotated).

Judging by the distances travelled by some of the Cordilleran terranes, spreading must have been occurring at a rate of about 10 cm yr⁻¹ in that part of the world during the Mesozoic; and the present deposition of the terranes suggests that subduction must have been highly oblique. The present rates of motion between the Ontong-Java plateau and Australia and south-east Asia, respectively, are also of the order of 10 cm yr⁻¹ and convergence is likewise oblique in the region between the Tonga and Philippine trenches. Furthermore the distances travelled from their source by the terranes marked W (Wrangellia) are comparable to that between eastern Indonesia and the Tonga trench. The geometries of the two situations also have similarities, with the Mariana trench being an analogue of the Aleutian trench, the Sorong fault being analogous to the Queen Charlotte fault, and Australia and the original North America being cratons of similar size.

The general conditions in the two regions, time difference apart, are thus remarkably alike, which would be of little consequence were it not for the fact that the Indo-Pacific region contains an abundance of precisely the types of fragment that made up western North America. Thus there are at least ten island arcs and three oceanic plateaus as well as numerous continental pieces, mélanges zones, marginal basins and ophiolites both small and large (some of the world's largest, in fact). Moreover, some of these fragments have also undergone processes comparable to those of the American terranes. Several rotations have already been demonstrated and some pre-subduction amalgamation of fragments has occurred. Another important similarity between the older terranes and the modern Indo-Pacific is the development of a fold and thrust belt between Australia and the collision zone and a zone of basement-rooted foreland folds.

Thus far, Silver and Smith have done little more than to draw attention to the anomalies of the analogy between the Mesozoic and modern regions, although it is clearly their hope that further study of what is occurring today in the latter will throw useful light on what happened earlier in the former. Meanwhile, however, it is worth remembering that although the suspect terranes of western North America are the most closely studied so far, such terranes also exist elsewhere around the Pacific (China, Japan, the USSR and so on) and may also occur around the edges of other oceans. The processes of drift and continental growth are likely to prove, in detail, very messy indeed.

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