LACHLAN FOLD BELT: AN ACTUALISTIC APPROACH TO ENVIRONMENTAL/TECTONIC INTERPRETATION

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I wish to advocate a rigorously actualistic approach to interpretation of the ancient environments and tectonic history of the Lachlan Fold Belt. The history of environmental/tectonic concepts for the Lachlan Fold Belt is essential background to my case.

The Geosyncline/Orogeny Paradigm

Present concepts of the ancient environments and tectonic history of the Lachlan Fold Belt (LFB) are the outgrowth of one hundred years of investigation of the encompassing Tasman Fold Belt (TFB).

Charles Schuchert named the Tasman Geosyncline in 1916, and the North American and specifically Appalachian influence on stratigraphic/tectonic thought about the TFB has been paramount until the present decade. The Appalachian Fold Belt is the type geosyncline, a term which Dana coined to describe it. With the Appalachians as his type, Schuchert stated in 1923:

> "... all of the geosynclines of North America form on the inner sides of borderlands which are but the diastrophically active margins of continents. Furthermore ... geosynclines are destined to evolve into mountains. This is the American theory of geosynclines and it is in direct opposition to the views of European geologists, especially as formulated by Haug in 1900. The fundamental difference between the two theories is that Haug places the geosynclines on the outer sides of continents in the areas of continental shelves. His studies centre on the history of Tethys, the greater Mediterranean, once extending from the Atlantic to the Pacific. This is a very deep and vast basin of the oceanic type, situated, however, between close-lying continents. Tethys was not therefore a geosyncline in the American sense, but a mediterranean ... To extend the meaning of the term geosyncline to all subsiding areas of sedimentary accumulation, to mediterranean and even to oceanic basins, as was done, it is true, for the first time by Dana, is to befog the brilliant idea of James Hall. Our understanding of geosynclines ... is that they are variably long and variably wide, very mobile, sinking areas that always originate within a continent."

Schuchert did at times link specific stratigraphic units of the Appalachians with specific modern depositional environments, but it seems he did not seek a modern environmental analogue for the Appalachian Geosyncline as a whole. Indeed he rejected Haug's actualism. Thus the concept of 'geosyncline' we inherited from Schuchert was essentially non-actualistic.

The North American geosynclinal concept inherited and elaborated by Schuchert had been developed by James Dana in the context of a cooling, contracting earth. Contractional folding at the margins of the great ocean basins formed geosynclines on continental borders and converted them into mountain ranges. This contractional folding was not continuous, but episodic on a global scale, with a tendency to coincide with period boundaries. Schuchert emphasized diastrophic periodicity much more strongly than Dana himself:

> "It is now well established that the geologic history of the earth is cyclic in its nature, cyclic in that the periods have long intermediate times when the lithosphere undergoes peneplanation and warping movements comprehended under the term *epeirogenic*, and shorter closing epochs when the earth's outer shell is locally folded into mountains, the *orogenic* times ... The cause of the cyclic changes in the surface of the earth is to be sought in the variable tensions in, and the elasticity of, the lithosphere. These are brought about by radial shrinkage, or the contraction energies. The tensions are of slow accumulation during epeirogenic times, and they give way to crustal movements during the orogenic epochs of compensation."

The prime Australian exponent of the North American geosyncline/orogeny paradigm was E.C. Andrews. In his 1937 paper on 'The structural history of Australia during the Paleozoic' he described the evolution of the TFB within a conceptual framework which was unmistakably North American:

> "... the Eastralian and Tasmanian Highlands themselves occupy the sites of two great Paleozoic geosynclines, or earth troughs, arranged within the peripheral portion of the continent, the one extending from Cape York to Newcastle, the other from Sydney to western Victoria, inclusive of Tasmania ...
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> "The geosynclines imply a close association with feeding geanticlines, not, necessarily, consisting of very high land, but, nevertheless, possessing vertical relief sufficient ... to produce the enormous loads of sediment accumulated within the neighbouring and sinking troughs.
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> "Each of the main geosynclines considered in this paper appears to have been loaded beyond the strength of its sinking (undulating) foundation; it was then compressed with its load, and thereupon became the site of a geanticline, and there appears to have been a general emergence of other areas in Australia associated with each great local compression."

By the time David and Browne's 'Geology of the Commonwealth of Australia' was published in 1950, the Schuchert/Andrews view of the TFB was firmly embedded in Australian geological literature. Browne characterized the Tasman Geosyncline as:

> "a sinking trough with submeridional orientation and with a wide curve convex to the east, steadily loaded with terrigenous sediment and periodically subjected to horizontal pressure from an earth-block lying to the east."

A Pacific Paradigm and the New Actualism

In this decade there has been an explosive development of a Pacific consciousness among geologists in eastern Australia, based on an enormous expansion of knowledge of the oceans in general and the western Pacific in particular. It is perhaps a scientific expression of the new nationalism that we in eastern Australia have at last adopted *Pacific* environmental models for the TFB.

The history of this indigenous viewpoint before the seventies is individual and sporadic, and until this decade it had almost negligible impact on investigation of the TFB. R.L. Stanton, a pioneer of the indigenous outlook, has written (1974):

> "In 1950 I was fortunate enough to be included in a small party engaged in geological mapping in the British Solomon Islands – a volcanic archipelago at that time geologically almost unknown. The enormous relevance to the work on mineralisation in NSW was immediately apparent. Here was a whole group of volcanic islands surrounded by coral reefs, on the seaward side of which sediments were accumulating. Such sediments were, *ipso facto,* of dominantly volcanic (pyroclastic) derivation, and I soon found that the lavas and pyroclastic rocks of the islands contained notable traces of sulphide. Here, it appeared, was a modern analogue of the ancient environment in which the Bathurst mineralisation occurred. It was at this time that I realised that certain ores – those that are now widely recognised as "stratiform" – were probably closely related to volcanic island arc formation."

I had a similarly illuminating and formative experience in 1963 on a geological reconnaissance of Espiritu Santo in the New Hebrides where I encountered rocks indistinguishable from those which I had mapped and studied near Wellington, NSW, in the previous year.

The revolutionary expansion of a Pacific consciousness amongst us in the seventies expresses a much deeper and more lasting change than the adoption of seafloor spreading and plate tectonic concepts. These concepts themselves are the product of a great actualist revolution based on the discovery of the nature of two-thirds of the earth's surface. Nowhere is this new actualism more clearly exemplified than by the sixties' revolution in concepts of the nature and evolution of the Appalachian Fold Belt. In 1959 the Lamont oceanographers, Drake, Ewing and Sutton, drew attention to the striking geometric analogy between shelf-to-rise sediment profiles of the Atlantic coast of North America and Kay's reconstructed Appalachian Geosyncline profile. This was followed in 1963 by Dietz's 'actualistic concept of geosynclines and mountain building', which used the essentially Atlantic Ocean concept of seafloor spreading as a basis for interpretation of Appalachian evolution. By 1970 Bird and Dewey could write of geosynclines, with the Appalachian as their type:

> "A geosyncline as constituted in the classic sense is, to us, an ocean with its island arcs, small ocean basins, and continental margin sediments . . . "

Actualism and Environments

Actualism, the kernel of the new approach to the geology of fold belts, is the constant effort to relate the remnant elements and configurations of ancient environments to those of modern environments. Geologic interpretations are actualistic to the degree that this match can be made, character by character. Actualism cannot be defended on the grounds that the past was unquestionably like the present. But I take an actualistic approach to be an historical form of the scientific simplicity principle. The simplest and therefore first hypothesis we should adopt is that the past resembled the present, and thus we should use observation and interpretation of the present as fully as we may in reconstruction of the past, and only go beyond it when its capacity to explain is exhausted.

A rigorous actualism demands a modern environmental analysis approach to first-order environments of sedimentation such as have yielded the LFB. Island arc interpretations of the depositional environment of the northern LFB have so far been based on general models founded on selected types such as the Marianas. Yet the degree of variation in configuration of arc systems in the western Pacific is enormous. These variants yield a similarly large store of modern analogues by comparison with which ancient configurations may be reconstructed. Such an approach requires a broad-ranging familiarity with modern configurations, and sufficient information on potential close analogues to permit to a substantial degree a character-by-character comparison of modern and ancient.

Actualism and Tectonics

Modern Pacific environments have totally displaced the horsetrough geosyncline of Schuchert in environmental interpretation of the TFB. But the paired concept of episodic or periodic orogeny lives on, sometimes incorporated uncritically within an alien Pacific framework. I am not suggesting that deformation, magmatism or any of the many effects encompassed by the term orogeny may not be coincident, with episodic or periodic recurrence, but rather that conclusions about the nature of such events should come from critical scrutiny of the evidence within the framework of new environmental and tectonic models. If we adopt an actualistic methodology, we must apply it uniformly. If we are prepared to replace geosynclines with ocean basins, large and small, then we must be prepared to replace orogenies with processes which go on or which we believe to be going on in those modern environments which serve as types or analogues.

Island Arcs and Fold Belts: a Small Ocean Basin Paradigm

A whole-hearted acceptance of the new actualism should not bind us passively to the concepts which have arisen with it. I am not at all convinced that plate tectonic models are well adapted to illuminate the tectonics of island arcs and fold belts. In my view, plate tectonics is basically a large ocean basin-centred view of global kinematics, effective and compelling in interpretation *at that scale.* The small ocean basins and their associated arcs may not be satisfactorily describable *at their scale* in terms of the relative movement of rigid or quasi-rigid blocks of lithosphere, especially over time intervals that are measurable in the Palaeozoic. In the small ocean basins average heatflow is much higher and lithosphere thicknesses proportionately less than in the large ocean basins. One would not expect them to exhibit the same kinematics as large ocean basins. We know from palaeomagnetic and radiometric evidence that, over tens of millions of years, island arcs like Japan, far from behaving as the brittle leading edges of rigid crustal blocks, have been plastically deformed on a whole-arc scale, despite being the thickest crustal segments of arc systems. The large number of microplates required in plate tectonic analyses of island arc systems is perhaps symptomatic of conceptual inappropriateness, as are such terms as 'plastic plates' now appearing in the plate tectonic literature.

As S.W. Carey has emphasized, the plate tectonic view of island arcs is essentially a corollary of seafloor spreading on an earth of constant radius. Thus the plate tectonic view of island arcs does not stem in the first instance from a necessity to explain their own *intrinsic characteristics.* I believe we need a small ocean basin paradigm which takes as its starting point the need to explain the characteristics of small ocean basins and island arcs *in themselves.* The nucleus of such a model has, in fact, been developed over four decades by pioneers of the new actualism, the Dutch earth scientists who have worked in Indonesia, especially van Bemmelen. Within the framework of a small ocean basin model, *orogenesis,* including magmatism, metamorphism and deformation, is a response to thermal flux centred on the small ocean basin and not driven by remote control from a large ocean basin.

PALAEOMAGNETISM AND THE STRUCTURAL HISTORY OF THE LACHLAN OROGENIC ZONE

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Comparison of palaeomagnetic and geological tectonic models of the Lachlan orogenic zone shows that modifications must be made to each in order for them to be consistent. The palaeomagnetic data resolve the geological problem of the situation of Tasmania in the Lachlan orogenic zone, while geological considerations show that a plate tectonic model is not a necessary explanation of the palaeomagnetic data and the rotations can be explained by internal deformation rather than block rotation.

Lachlan Orogenic Belt

Palaeomagnetic data for the Lachlan orogenic belt (excluding Tasmania) are described by Briden (1966) and Luck (1973). The pole positions are listed in Table 1.

Formation mean site coordinates	Age	Pole Lat.	Coordinates Long.	Reference
Silurian volcanics (SV) 34.7°S 148.9°E	Sm-u	54°S	271°E	Luck (1973)
Mugga Mugga Porphyry (MM) 35.1°S 149.4°E	S (423)	80°S	340°E	Briden (1966)
Bowning Group (BG) 34.5°S 148.8°E	Dl	64°S	45°E	Luck (1973)
Ainslie Volcanics (AV) 35°S 149°E	Dl	71°S	353°E	Luck (1973)
Housetop Granite (HG) 41.3°S 145.9°E	D (375)	67°S	94°E	Briden (1967)
Lochiel Formation (LF) 37.2°S 149.8°E	Du	58°S	320°E	Luck (1973)
Mulga Downs Group (MD)	Du	54°S	103°E	Embleton (1976) (unpublished)

TABLE 1
Summary of palaeomagnetic data for the Lachlan fold belt

A first order fit of the polar wander curves (Fig. 1) shows a discrepancy between the Lachlan orogen and the Australian platform, interpreted within the framework of the plate tectonics as due to differential rigid rotations (McElhinny and Embleton, 1974, and Embleton *et al.,* 1974). The curve for the platform is based on results from northern Australia (the Antrim Plateau Volcanics, AV; the Hudson Formation, HF, and the Jinduckin Formation, JF), central Australia (the Arumbera Sandstone, AS; the Hugh River shale, HS; the Stairway Sandstone, SS, and the Mereenie Sandstone, MS), South Australia (the Lake Frome Group, LFG, and sediments at Aroona Dam, AD), Western Australia (the Tumblagooda Sandstone, TS), Tasmania (the Dundas Group, DG, and the Housetop Granite, HG) and the Mulga Downs Group, MD, from western New South Wales. All of these pole positions except MD are listed by Embleton and Giddings (1974). The data for the Lachlan fold belt are listed in Table 1. For completeness, the Permo-Carboniferous pole position – valid for the whole of Australia – is also shown (open circle). This was an attempt to quantify the 'block accretion' geological models of Oversby (1971), Solomon and Griffiths (1972) and Scheibner (1972).

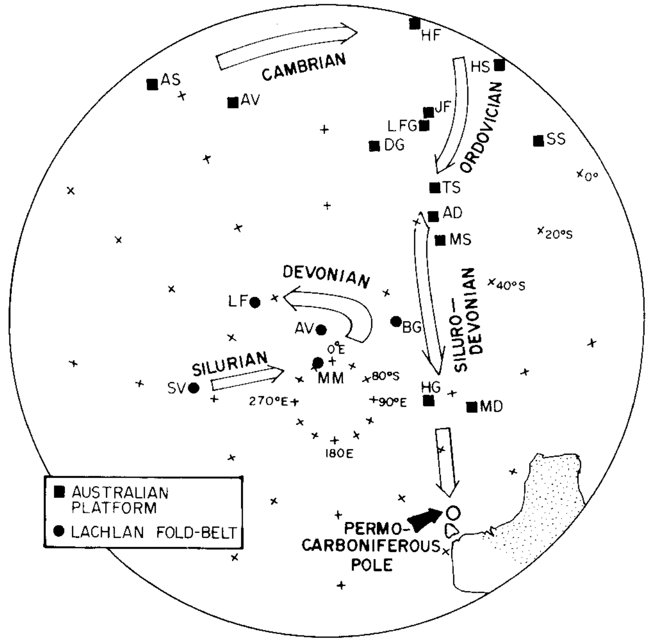

FIGURE 1
Apparent polar wander for the Palaeozoic relative to the Australian platform (stippled) and the Lachlan fold belt.

In the Lachlan orogenic belt there is stratigraphic evidence of four deformational episodes, termed the Benambran, Bowning, Tabberabberan and Kanimblan, with effects as portrayed by Scheibner (1974b). We restrict discussion to the Kanimblan (Early Carboniferous).

Palaeomagnetic evidence relevant to the Kanimblan orogeny is available only from widely separated sites: the Upper Devonian Lochiel Formation sampled at 149.8°E, 37.2°S (Luck, 1973) and the Upper Devonian Mulga Downs Group sampled at 143.5°E, 32.8°S (see Table 1).

New data from the Upper Devonian rocks of eastern Victoria (P.W. Schmidt, personal communication) and the