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John F. Dewey

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COMMENTARY

MARKING 50 YEARS OF THE WILSON CYCLE

Tuzo Wilson: An Appreciation on the 50th Anniversary of His 1966 Paper

John F. Dewey

University College Oxford
High Street, Oxford OX1 4BH, United Kingdom
E-mail: jfdeweyrocks@gmail.com

John Tuzo Wilson probably had a greater influence on the development of the earth sciences than any geologist since William Smith and Charles Lapworth. Prior to the early 1960's, he was a staunch anti-drifter but, in 1965, he pulled together many threads to create a cohesive paradigm that embraced continental drift, sea-floor spreading, subduction, and very large motions on transcurrent faults that defined the boundaries of and sites of relative motion between plates, the basis of what would come to be known as plate tectonics. Implicit in his analysis was the torsional rigidity of plates. Torsional rigidity means that plates have sufficient strength to avoid distortion in map view although they may be distorted along their edges (plate boundaries) and are more easily distorted by flexure in cross-section. Apart from the well-known contributions of Wegener (1929), Holmes (1931), Griggs (1939), Creer et al. (1958), Hess (1962), Runcorn (1962), Heezen (1960), Dietz (1961), and Vine and Matthews (1963), two lesser known and appreciated observations were instrumental in the formulation of plate tectonics. First, Harry Wellman (1955) already recognized that the Alpine Fault in New Zealand joined trenches with opposite polarities and is elongating. Secondly, Bert Quennell (1958) described the sinistral relative motion of Africa with respect to the Arabian Plate along the small circle of the Dead Sea Fault around a rotation pole near Gibraltar, implying torsional rigidity of the adjacent blocks. Simultaneously with Tuzo's 1965 paper, Bullard et al. (1965) assumed torsional rigidity to make finite difference rotations around poles of rotation, to achieve fits and minimizing misfits, between the continents around the Atlantic. McKenzie and Parker (1967) described the relative motion among the torsionally rigid Pacific, North American, and Gorda plates and the theory of plate tectonics was born. Tuzo's fundamental role came between 1962 and 1965 in his papers on the Cabot Fault (1962), and interpretations of oceanic islands (1963a) and Hawaii (1963b) as hot-spot tracks, culminating in his definitive 1965 paper that founded plate tectonics and his clever paper (1966) on the Caribbean and Scotia plates moving through gaps between continents and invading 'innocent' oceans with rifted margins. Strangely, Tuzo did not use rotation poles to describe relative motion among his global plate mosaic, in spite of the implicit rigidity of plates, even though used, explicitly, by Wellman, Quennell, and Bullard et al. Within a few years, plate tectonics was developed as a quantitative, integrated theory by McKenzie and Parker (1967), Morgan (1968), Le Pichon (1968), and Isacks et al. (1968).

Figure 1. There are many 'official' pictures of Tuzo Wilson, but it seems more appropriate to use this lovely photograph by renowned Canadian photographer Harry Palmer, and we reprint it with his kind permission. Harry took splendid and candid photographs of many 'Companions of the Order of Canada,' and Tuzo was awarded this honour in 1969, three years after his famous paper.

Of great importance in tectonics, during this period, was Tuzo's 1966 paper, "Did the Atlantic close and then re-open?" (Tuzo enjoyed framing his papers as questions, which many journals no longer allow). In 1965, I was a young lecturer in Cambridge deeply absorbed in developing new courses in

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structural geology and working on the geology of western Ireland, Nova Scotia, and Newfoundland. Both Harry Hess and Tuzo were on sabbatical leave in Madingley Rise, the then Department of Geophysics in Cambridge presided over by Teddy Bullard. I owe these three earth scientists more than I can say in transforming my approach to geology, in their advice to expand my horizons to include a global tectonic scale. Tuzo came into my room in the Sedgwick Museum many times for morning coffee and chats about regional and global geology, especially the relationship between structural geology and tectonics. One morning, with that inscrutable gentle smile that usually characterized his face, he announced "I have discovered a new class of fault." I confess that I was sceptical until he drew from his bag his now-classic paper model of a ridge-to-ridge transform and repeatedly opened and closed it under my nose. I was transfixed by the spectacle of a spreading ridge offset by a transcurrent fault that had the opposite sense of motion to that intuitively thought of as displacing the ridge axis along a classic transcurrent fault. Once seen, the pattern is obvious but was the most exciting thing in geology that I had witnessed in my short career thus far. It was even more fulfilling and instructive as Tuzo spent the next hour with me cutting up cards to illustrate the offsets along faults that connected trenches with the same and opposite polarities, ridges to trenches with ridge-facing and ridge-opposed polarities and several kinds of triple junction. Tuzo told me that he was about to publish all this as a coherent global model (his 1965 paper) and that he would introduce the term 'transform' for large-offset lithosphere-cutting faults that terminate at a ridge, trench or triple junction. Thus, he established the global pattern of continuous plate boundaries. I still have that model and the pieces of card (Bristol Board upon which I drew most of the illustrations for my papers until the digital revolution of Adobe Illustrator) as one of my most treasured possessions. As if all this was not enough, the following month Tuzo strode into my room and (paraphrasing) announced "my global model means that continents are carried around as passengers that oceans open with trailing rifted margins and close with collisions that make mountain belts. It seems to work for the Appalachian–Caledonian Orogenic Belt in relation to the Atlantic Ocean. The Orogen was probably developed by the closing of a Lower Palaeozoic ocean and split to form the present Central and North Atlantic leaving bits of the margins of the Lower Palaeozoic ocean (now termed Iapetus) on both sides of the present Atlantic." In 1973, Burke and Dewey coined the term 'Wilson Cycle' to describe the opening and closing of oceans. Tuzo showed me a draft of a paper that he had begun to write that appeared in *Nature* in 1966. This, together with my work with Art Boucot and Stuart McKerrow in Nova Scotia and Marshall Kay in Newfoundland in 1964, Bob Jastrow's Goddard Conference in New York in 1965 and further work in Newfoundland in 1966, developed my interest in trying to understand the Northern Appalachians and the British and Irish Caledonian Orogen. By serendipity, Chuck Drake was on sabbatical leave in Cambridge in 1966 and, knowing of my Appalachian interests, invited me to Lamont for a six month sabbatical leave in the second half of 1967. While in Lamont, the whole picture of plate tectonics was solidifying as a 'complete' theory with the work of Morgan, McKenzie and Parker, Le Pichon, Isacks et al., and Pitman. During the sabbatical, I developed a tectonic map of the Appalachian and Caledonian Chain, on a massive roll of tracing linen, upon which I plotted Lower Palaeozoic continental shelves/platforms, ophiolites, island arcs, subduction zones, collision zones and all the geological corollary hallmarks of

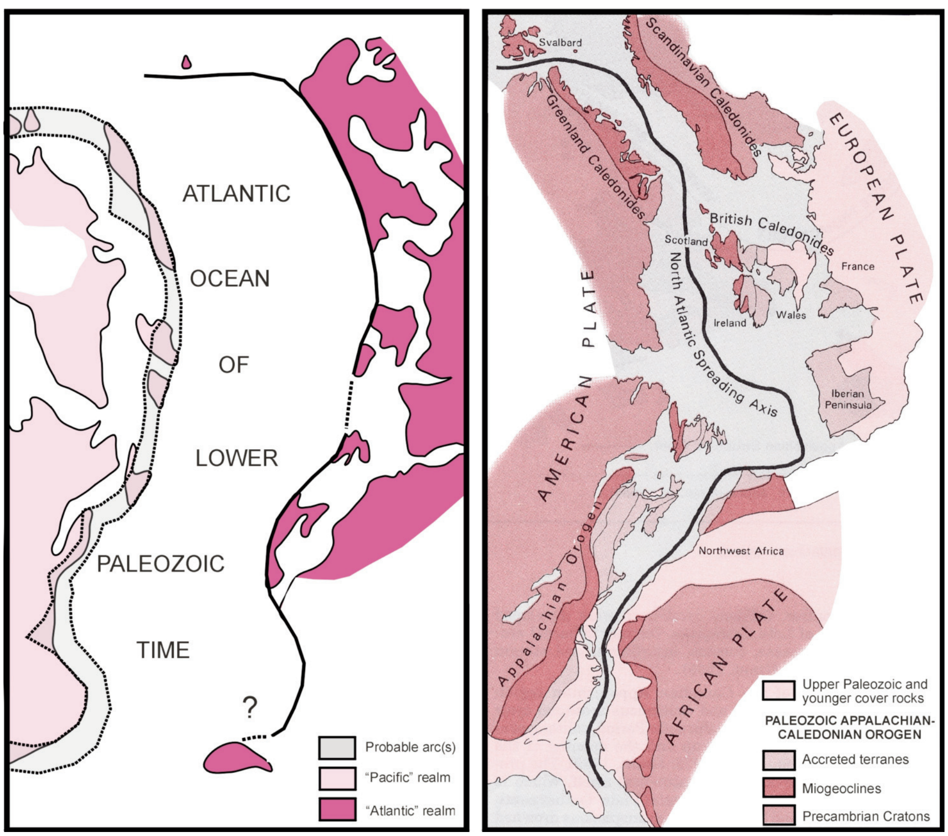

Figure2. The changing views of the North Atlantic borderlands.
On the left is a redrawn coloured version of the hand-drawn Figure 3 from Tuzo's 1966 paper in *Nature*, showing the concept of his "Atlantic Ocean of Lower Paleozoic time." We see the inference that parts of Scandinavia and the British Isles were once part of the North American continent, and that parts of eastern North America more properly belong with Europe or Africa. On the right is a later reconstruction of the Appalachian–Caledonian Orogen by Hank Williams, from the Decade of North American Geology volume (Williams 1995), showing the spreading axis of the modern North Atlantic. It incorporates more detail on the components of what we now call 'Iapetus,' but its heritage remains clear. This analysis remains a cornerstone of regional geology and tectonics in our 21st century, and it is a direct descendant of Tuzo's prescient thinking in 1966. Wilson's (1966) paper, "Did the Atlantic close and then re-open?" surely deserves recognition as one of the most influential contributions to geological science.

plate tectonics, which led to a string of papers, e.g. Dewey and Kay (1968), at the same time as those of many others, such as Atwater (1970), Hamilton (1969), and Smith (1971).

In all this, Tuzo was my main influence, inspirer, and principal encourager for which he has my eternal gratitude and respect. Like Bullard and Hess, Tuzo was a kind and generous man with his time, ideas, and encouragement of the young. His mind was quick, fertile, and imaginative with an astonishing capacity for organizing, analyzing, and synthesizing huge amounts of data. Above all, he was prepared to admit that he was wrong and changed his mind in a flash. He was brilliant at asking the right question and following it up with a prodigious amount of reading and plotting, seeing through and casting aside irrelevance, and linking apparently disparate notions and data coherently. He was always well-dressed in suit and tie with a polite but confident demeanor, seemingly happy and contented. He is remembered as a brilliant and original synthesizer who formulated global plate tectonics. He remarked to me and to Kevin Burke that, if he had known Euler's Theorem (a method of finding the simplest paths between once contiguous points), he would have 'nailed' plate tectonics cold. It is significant that Harold (Hank) Williams gained his PhD at the University of Toronto in 1961 under the supervision of Tuzo Wilson. Williams unleashed a productive period in our understanding of the geology of Newfoundland (e.g. Williams 1979) and the opening and closing of Iapetus. One might fairly say that Tuzo's 1965 paper changed the course of global tectonics and that his 1966 paper led to a complete new understanding of the implications of his 1965 paper for the origin of mountain belts resulting from super-continent cycles, the most important paradigm change in the history of geology.

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