Features

History of Canadian Geology

R. K. Stevens
Department of Geology
Memorial University of Newfoundland
St. John's, Newfoundland

The Taconic Problem has taken several different forms during the last hundred years or more and the attempts made to resolve it have had a major influence on the evolution of geological thought. Geologists attempting to come to grips with the Taconic Problem have been likened to blind men trying to describe an elephant but only randomly touching various parts of it (Zen, 1967). Of course, they all come up with different descriptions depending on the part of the animal they happened to touch. It is not generally realized, however, that Sir William Logan came close to our present understanding of the whole animal and in so doing introduced several novel concepts to the science of geology.

In Canada, the Taconic Problem is mainly concerned with the Quebec Group in Quebec and the Humber Arm Group in Newfoundland. Both were correlated at an early date with the Taconic rocks in New England. The Quebec and Humber Arm Groups comprise complexes of sedimentary, metamorphic and igneous rocks that occur between the little deformed rocks of the platform and the highly deformed and metamorphic core of the Appalachian system.

Logan (1863a, p. vii) admitted in his introduction to the Geology of Canada that "The age of those rocks which are now termed the Quebec Group, was, from an early period of the Survey, a subject of considerable difficulty." Even when the age problem was resolved there still remained the vexing problems of field relationships and paleogeography. What is the present relationship of the Quebec Group to other units in the Appalachians and what was its original relationship?

The way in which Logan and his coworkers faced these problems of paleontology, correlation, structure and paleogeography is of some historic interest for it involved one of the first discussions of tectonics and sedimentation at an ancient continental margin.

We are fortunate that Logan recorded the evolution of his thoughts in his correspondence as well as in the introduction to his Geology of Canada.

First Impressions

Logan was not the first geologist to study the rocks in the Quebec City area. Earlier work had been done by J. J. Bigsby (1828). He had concluded that the rocks later to be called the Quebec Group rested conformably on the underlying Trenton limestones. At first Logan disagreed with this view when he investigated the rocks in 1840. Logan thought that the rocks of the Quebec Group were much more deformed than the Trenton and must, therefore, be older and somehow underlie the Trenton (Logan, 1845). He was forced to give up this intuitive interpretation when he found that there was no apparent stratigraphic break between the two sequences. A section of dark coloured shales, the Utica and Hudson River formations linked the Trenton to the overlying Quebec Group. Logan reverted to Bigsby's interpretation and recorded his change of mind in a footnote to the 1845 report. This revision is emphasized in several later reports.

For over 17 years Logan held to this view and believed that the structural, stratigraphic and paleontological evidence supported it.

Colonies and the Reformation 1860

Nevertheless, fossils are not scarce in some parts of the Quebec Group. Bigsby (1828) obtained many fossils from limestone conglomerates at Levis but since these came from clasts he naturally thought that they had been derived from the underlying Trenton or older limestones. Logan collected graptolites at Point Levis in 1854 and two years later Sterry Hunt obtained a large collection of "shelly" forms from the same areas. From 1856 to 1860, substantial fossil collections were made at Levis by various members of the Survey (Harrington, 1883, p. 342) but for several reasons their significance was not realized. Even so the time and trouble taken to collect the fossils by an overworked survey might reflect at least a residual discomfort with a stratigraphy that placed old-looking deformed rocks on top of undeformed rocks.

Elkanah Billings joined the Survey in 1856 and, as paleontologist, was responsible for describing the Levis fauna. His main effort was directed towards correlating the Levis section with certain central European sections which were becoming increasingly well known through the endeavours of the French emigré Barrande. Gradually Billings came to realize that the Levis fauna was much more primitive than expected. Not only did it look older than that of the underlying shales, but it seemed older even than the Trenton fauna and to correlate best with faunas at the base of Barrande's second fauna or about the level of the Calciferous or Chazy Formations; that is, low in the Ordovician. This correlation could not be reconciled with the stratigraphy worked out and published by Logan and was a matter of great concern to the Survey. Their difficulties were not unique.

Barrande had encountered similar problems during his work in Bohemia. In places he found fossils well out of their normal stratigraphic order. Silurian graptolites turned up, somewhat disconcertingly, in the middle of a supposedly Ordovician sequence (Bailey *et al.*, 1928, p. 581). To explain these anomalies, Barrande devised his theory of colonies in 1851. According to this theory, organisms did not reach the same degree of development throughout their entire geographic range. Although Ordovician graptolites gave way upward to Silurian forms, this did not happen at the same time all over the world so that an influx of certain forms could temporarily occupy an area frequented by primitive forms. Colonies of Silurian-type graptolites might pass through an area occupied by Ordovician forms. In this way, Barrande explained the faunal anomalies he observed.

At first, Billings used a slightly modified version of Barrande's theory of colonies suggesting that colonies of primitive animals might have survived locally in the midst of more advanced forms (letters from Billings to Barrande written in March or April 1860, quoted by Logan, 1863a, p. viii). Billings was suggesting that local colonies of Lower Ordovician forms survived until Middle Ordovician times or later to explain the Levis fossils, a noble attempt to reconcile field data and paleontology. It must be remembered that Darwin's *Origin of the Species* was only five years old and its implications were not fully realized by paleontologists. There were no theoretical objections to colonies, and field relationships seemed to support the hypothesis.

In May 1860, however, Logan and Head made new fossil discoveries at Levis. Although I have not been able to find out what the new finds were, they were important enough to wreck the theory of colonies and destroy Logan's field interpretations. By June 12, 1860, Billings was convinced that the Levis faunas were truly of Lower Ordovician age correlating with the faunas at the base of Barrande's second fauna and so informed Barrande. Billings saw that the theory of colonies could not explain the Levis faunas because of its exclusively primitive aspect. It was not a case of a few primitive forms associated with younger forms but one in which 137 species showed a uniform primitive aspect (Logan, 1860, p. 474). Furthermore, "of this fauna not one species is found in the Anticosti Group, where we have a gradual passage from the fauna of the Hudson River formation to that of the Clinton . . ." (Logan, 1860, p. 474). Not a single fossil could be found in the Levis that was the same as ones found in rocks that appeared to occupy the same stratigraphic position elsewhere.

Billings, "with much judgement and a certain amount of good fortune" (Bailey *et al.*, 1928, p. 482), transferred the Levis Formation from a position high in the Ordovician to one low in the Ordovician. Bailey *et al.*, (1928) called this revision "The 1860 Reformation". It presented a considerable challenge to the Survey. In the light of the new paleontological data, how could the Levis Formation and hence the great mass of the Quebec Group rest conformably on the Trenton? Either their stratigraphic or paleontological methods were wrong; or perhaps both were. Whatever the outcome, much of the Survey's now published-work would have to be revised with a consequent loss of credibility.

After Logan published his solution, James Hall wrote: "In a conversation with Sir William which I had in September 1860 he then assured me that there was no possibility of there being any break, overturn or other condition that could in the least interfere with his conclusions that these were one and the same groups. In November I had the same assurances from him after he had revisited and re-examined Quebec – and it was not until late in December that he wrote me that there must be a break, upon paleontological grounds, but that it did not affect Hunt's chemical results or generally alter it. Now I cannot see but both Logan and Hunt must give up their mode of working and their results amount to nothing."

"I think Sir William cannot see that by these admissions he takes out his props to his physical and topographical geology everywhere in Canada and renders it as worthless as he confesses this great work on the Green Mountain range to be – and not only this, confesses the worthlessness of his chemical geology too, and he leaves his enemies, if he has any, to take advantage of the circumstances." (Letter from J. Hall to J. P. Lesley, 1861, quoted in Merrill, 1924, p. 729).

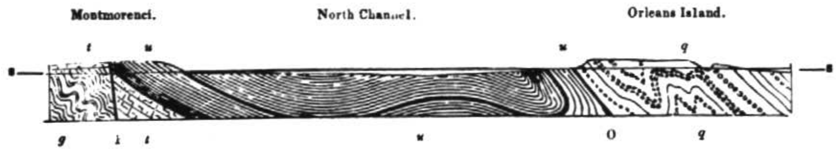
Marcou offered another explanation of the fossils, differing somewhat from that of Logan's. ". . . I left the Point fully convinced that the fossils described by Mr. Billings, and the so-called outcrops, A^2, A^3, A^4, etc., of Mr. Logan, were collected and observed in a very careless way, without regard to stratigraphy, by irresponsible collectors, or by unskillful practical geologists." (Letter to Barrande dated August 2, 1862, quoted and rebutted by Logan, 1863b). In short, both Hall and Marcou suggested that Logan should turn in his hammer. These inflamatory opinions were voiced at a time when the Survey was struggling for government support and financial survival (Harrington, 1883, p. 353-360). The Survey, however, defended itself in a spirited manner suggesting that they had been misled by an over dependence on Hall's faulty paleontological work!

The Great Dislocation

The letter from Hall to Lesley quoted above indicates that in September and November 1860, Logan and Hall had discussed the possibility of overthrust faulting in the Quebec City area but had ruled it out. By late December, Logan had changed his mind and wrote to Barrande: "From the physical structure alone no person would suspect the break that must exist in the neighbourhood of Quebec, and without the evidence of the fossils, every one would be authorized to deny it. If there had been only one or two species of an ancient type, your own doctrine of colonies might have explained the matter, but this I presume would scarcely be applicable to so many identities in a fauna of such an aspect. Since there must be a break, it will not be very difficult to point out its course and its character. The whole Quebec group, from the base of the magnesian conglomerates and their accompanying magnesian shales to the summit of the Sillery sandstones, must have a thickness of perhaps some 5000 or 7000 feet. It appears to be a great development of strata about the horizon of the Chazy and Calciferous, and it is brought to the surface by an overturned anticlinal fold with a crack and a great dislocation running along the summit, by which the Quebec group is brought to overlap the Hudson River formation. Sometimes it may overlie the overturned Utica formation, and in Vermont points of the overturned Trenton appear occasionally to emerge from beneath the overlap."

"A series of such dislocations traverses eastern North America from Alabama to Canada. They have been described by Messieurs Rogers and Safford. The one in question comes upon the boundary of the Province not over a couple of miles from Lake Champlain. From this it proceeds in a gently curving line to Quebec, keeping just north of the fortress; thence it coasts the north side of the Island of Orleans, leaving a narrow margin on the island for the Hudson River or Utica formation. From near the east end of the island it keeps under the waters of the St. Lawrence to within eighty miles of the extremity of Gaspé. Here again it leaves a strip of the Hudson River or Utica formation on the coast" (Logan, 1860). Logan's dislocation is shown in Figure 1.

Unfortunately, we do not know exactly how Logan arrived at the concept of overthrusting to explain the paleontological data. A few



Horizontal and vertical scale, one inch to a mile.

g, **Laurentian gneiss.**
t, **Trenton limestone.**
u, **Utica and Hudson River formations.**
q, **Quebec group.**
F, Fault.
O, Overlap.
S, Level of the sea.

Figure 1
Section from Montmorenci to Orleans Island, showing Logan's Great Dislocation, O. (from Logan, 1863a).

overthrusts had been described previously so the concept was not new but those thrusts are well-exposed and obvious in the field and did not rely on somewhat controversial paleontological data for substantiation.

It is generally agreed that the first overthrust to be recognized was that described by Weiss in 1826 who found ancient granite thrust onto Cretaceous strata (*in* Hubbert and Rubey, 1959). But it seems as if the thrusts associated with folding in the Central and Southern Appalachians described by the Rogers brothers (1843) together with Safford's (1856) descriptions of thrusts in the same area provided the major trigger for Logan's inspiration (Logan, 1863a, p. 475). It is not impossible that the small-scale thrusts clearly visible in the bluff behind the Victoria Hotel where Logan stayed during field work in the Quebec City area also helped crystallize Logan's concept of the Great Dislocation.

To put Logan's discovery of the Great Dislocation into perspective, it is necessary to emphasize the difficulty of visualizing the lateral movement of great rock masses over large distances and the natural tendency of most geologists to search for alternative explanations. The well exposed and obvious Moine thrust in the Highlands of Scotland brings high grade metamorphic rocks on to sedimentary rocks. The history of its discovery makes interesting reading (McIntyre, 1954). When Sir A. Geikie finally accepted the existence of the thrust it so startled him that he wrote: "Had these sections been planned for the purpose of deception, they could not have been more skillfully devised" (Giekie, 1884). A few years earlier, A. G. (probably Archibald Giekie) reviewed Murray and Howley's book on the Geology of Newfoundland (A. G. 1876). He used the observation that metamorphic grade increases upwards in the Bay of Islands area of Newfoundland, so that gneisses apparently grade down into undeformed sediments, as supporting evidence that the Moine Thrust did not exist. It was not until 1970 that it was realized that the upwards increasing metamorphism was caused by a powerful thrust fault and this fault was a splay off Logan's Great Dislocation.

A textbook was published as recently as 1923 which denies the existence of thrust faults (Price, 1923). The puzzled author wrote: "But all such incredible movements of the strata are necessitated by the simple fact that the fossiliferous strata happen to be found in the wrong order." He turned to Heim for an explanation. Heim replied "the most incredible mechanical explanation is more probable than that the evolution or organic nature should have been inverted in one country, as compared with another" (Price 1923, p. 636-637). Much of Price's book is devoted to showing that both overthrust faulting and evolution are affronts to common sense. Logan must have faced much difficulty convincing his contemporaries that his Great Dislocation existed, since such faults were novelties in geology and the theory of evolution was only a few years old and not really incorporated into the fabric of paleontology. Logan's hypothesis should be judged against this background.

Paleogeography

If part, at least, of the Quebec Group was coeval with the Chazy of Calciferous Formations, why were the two groups of rocks so different in character? Logan's answer was that the Chazy and related rocks were deposited on the platform while the Quebec Group was deposited at the old continental margin of North America (Figs. 2 and 3). The distribution of rocks that Logan thought could be correlated with the Quebec Group marked for Logan the Lower Paleozoic continental edge of North America. According to Logan (1863a) the margin trended southwest from Quebec City to Alabama but then ran north-westwards to Kansas and from there to Lake Superior where Logan correlated the "copper-bearing rocks" with volcanic rocks of the Quebec Group. The Paleo-Atlantic lay to the east of North America (Fig. 3).

The configuration of the underlying Laurentian basement played an important part in Logan's scheme. Not only did it give shape and form to Lower Paleozoic North America but also controlled the position of the Great Dislocation. The break in slope of the basement marked the change from shelf to marginal sediments and the Great Dislocation was essentially the result of pushing the marginal sediments up the basement slope. The slope was rather steep, about 45 degrees. Logan preferred not to speculate on the origin of the forces that crushed the old continental margin but suggested that they acted normal to the margin and pushed from the ocean to the continent.

The break in basement slope, according to Logan, also controlled sedimentary facies. On the continental side of the slope shallow water sediments accumulated, though somewhat sporadically. Logan evolved a complicated history of

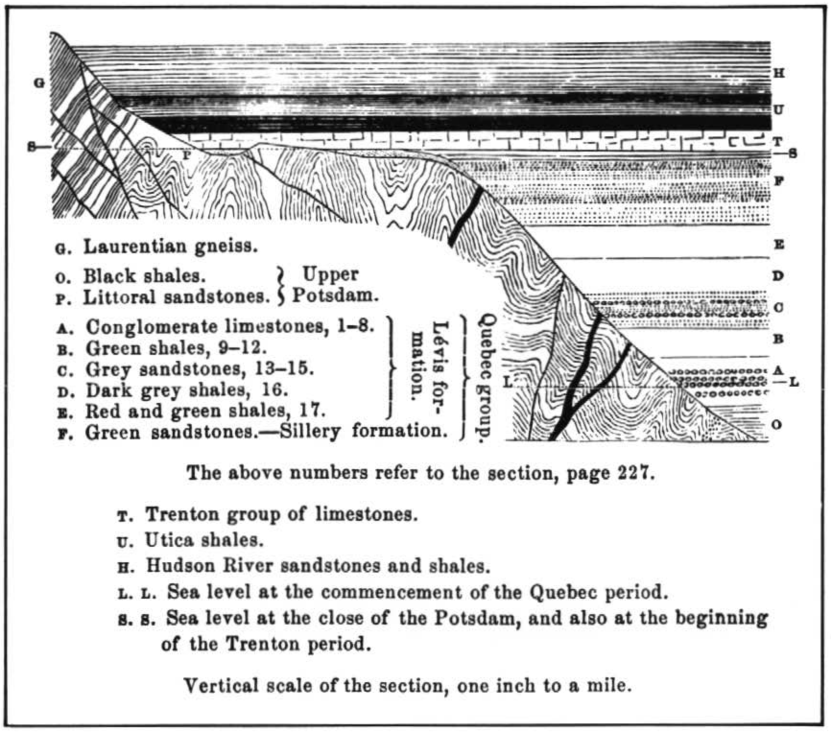


Figure 2
Disposition of the Quebec Group before thrusting. (from Logan, 1863a).

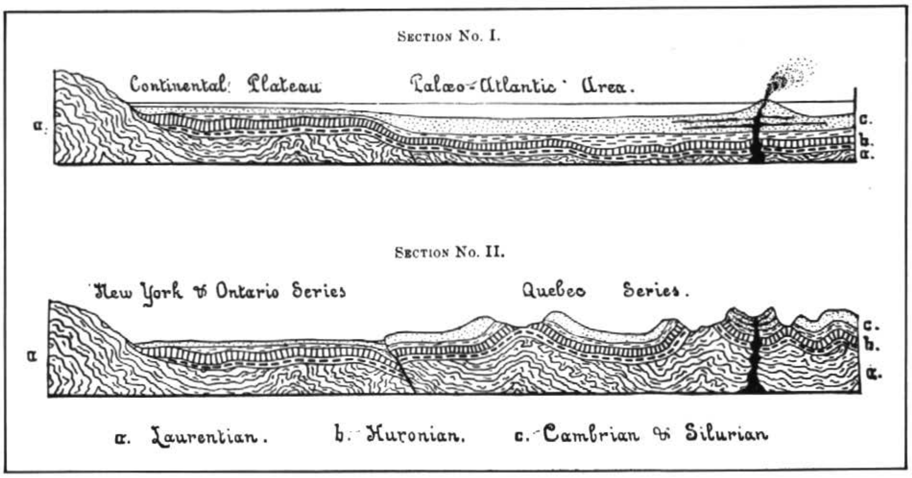


Figure 3
Logan's concept of the ancient margin of North America before deformation (section 1) and after (section 2). According to Dawson, in Harrington, 1883.

sedimentation farther down the slope involving great oscillations of relative sea-level. Coarse conglomerates have, until recently, been interpreted as shallow water deposits so Logan was forced to invoke shallow water conditions for the deposition of the conglomerates in the Quebec Group. Since these are interbedded with graptolite-bearing shales which Logan considered to have been deposited in deep water, oscillations in sea-level were a necessary part of Logan's scheme. Superimposed on this pattern were volcanogenic sediments, sediments deposited from cold Arctic currents and sediments resulting from submarine earthquakes.

Influence and Legacy

The most recent tectonic map of Canada shows Logan's Line, as the Great Dislocation came to be known, running through Quebec City and then under the St. Lawrence River well north of where Logan showed it and where it actually is (Fig. 4). Much of Logan's hypothesis was either ignored, disbelieved or misunderstood in the same way that Roman generals treated the first reports of Hannibal's elephants; the generals quickly learnt better. There are several possible reasons for rejection or misunderstanding of Logan's hypothesis. To start with, it is demonstrably wrong in several respects. Logan's stratigraphy within the Quebec Group has not survived. Neither has his correlation of the Quebec Group with the Proterozoic rocks of the continental interior.

Perhaps the most serious deficiency of Logan's hypothesis was the assertation that the Great Dislocation was a relatively high angle fault (Figs. 1 and 3). It is now postulated that the dislocation is essentially parallel to the bedding of both the hanging and footwall rocks but that it has been folded by later deformations so that it now has a steep dip over much of its outcrop area. Furthermore, a consensus has developed that Logan's Line is the structural front of the Appalachian system marking the junction between deformed and undeformed rocks. The latest tectonic map of Canada appears to have been constructed on this assumption. This assumption holds in some areas such as Quebec but in other areas such as Northern Newfoundland the thrust front and later fold front are not coincident. Logan's Line is not the deformation front but the most western exposure of the Great Dislocation.

The parts of Logan's hypothesis that have most appeal presently are those concerned with sedimentation on the margins of the Paleo-Atlantic and the interaction between continent and ocean during deformation of the margin (Fig. 4). This part of Logan's work is a precursor to much current research.

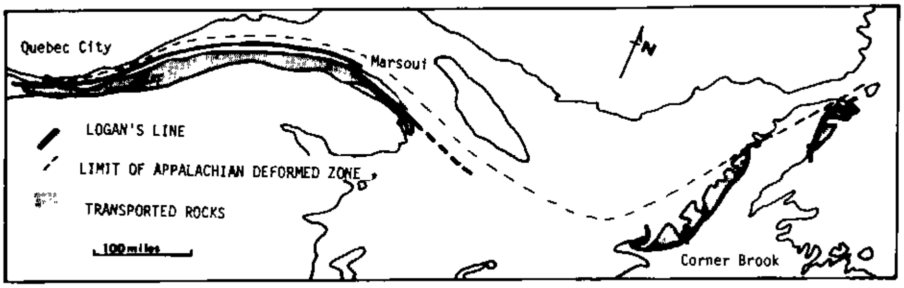


Figure 4
The trace of Logan's Line and the approximate position of the western limit of deformation in the Appalachians.

Acknowledgements

Research for this study was partially financed by an N.R.C. grant to W. R. Church. Thanks are extended to D. F. Strong and H. Williams for critically reading the manuscript and to L. Dickson for drafting Figure 4.

References

A.G., 1876, The Geological Survey of Newfoundland: Nature, v. 14, p. 254.

Bailey, E.B., L.W. Collet and R.M. Field, 1928, Paleozoic submarine landslips near Quebec City: Jour. Geol., v. 36, p. 577-614.

Bigsby, J.J., 1828, On the Geology of Quebec and its vicinity: Proc. Geol. Soc. London, v. 1, p. 37.

Giekie, A., 1884, The crystalline rocks of the Scottish Highlands: Nature, v. 24, p. 29-35.

Harrington, B.J., 1883, Life of Sir William E. Logan, Kt.: Montreal, Dawson Bros., 432 p.

Hubbert, M.K. and W.W. Rubey, 1959, The role of fluid pressure in overthrust faulting: Geol. Soc. Am. Bull., v. 70, p. 115-166.

Logan, W.E., 1845, Progress report up to 1843: Montreal, Geol. Surv. Can.

Logan, W.E., 1860, Remarks on the Fauna of the Quebec Group of Rocks, and the Primordial zone of Canada, addressed to Mr. Joachim Barrande. Can. Nat. and Geologist, v. 5, p. 472-477.

Logan, W.E., 1863a, Geology of Canada: Montreal, Dawson Bros., 983 p.

Logan, W.E., 1863b, On the rocks of the Quebec Group at Point Levis (Letter addressed to Barrande, March 15th, 1863): Can. Nat. and Geologist, v. 8, p. 183.

Merrill, G.P., 1924, The First One Hundred Years of American Geology: New York, Hafner, 773 p. (reprinted 1969).

McIntyre, D.B., 1954, The Moine Thrust – its discovery, age, and tectonic significance: Proc. Geol. Assoc. London, v. 65, p. 205-220.

Price, G.M., 1923, The New Geology: Mountain View, California, Pacific Press, 726 p.

Rogers, W.B. and H.D. Rogers, 1843, On the physical structure of the Appalachian chain, as exemplifying the laws which have regulated the elevation of great mountain chains generally: Assoc. Am. Geol. Rept., p. 474-531.

Safford, J.M., 1856, A Geological Reconnaissance of the State of Tennessee: Nashville, Mercer, 164 p.

Zen, E-an, 1967, Time and space relationships of the Taconic allochthon and autochthon: Geol. Soc. Am. Spec. Paper 97, 107 p.

MS received, February 25, 1974.