SPECIAL ARTICLE

UNCONVENTIONAL THINKING IN EARTH SCIENCE

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This paper was presented by Professor R.W. Hutchinson at the R.L. Stanton Symposium "Frontiers in Ore Deposit and Exploration Studies" during the 10th Australian Geological Convention in Hobart in February this year. The symposium was held in recognition of the outstanding contribution by Professor Stanton to ore deposit research and exploration philosophy.

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ABSTRACT

Uncertainty in earth science results from the many complex and inter-related qualitative factors that must be considered, and from evolutionary changes in them through time. Quantification is therefore difficult and these inherent deficiencies call for strict adherence to scientific method.

Interpretive hypotheses about the past processes that have shaped the earth ore inevitably imperfect, but their failings are too often overlooked and they ore accepted as fact, so that they become conventional and dogmatic. Research then becomes introverted in attempting to demonstrate the validity and universality of the established concepts. Scientific progress is impeded because the inherent failings of the conventional interpretation are obscured and perpetuated, rather than corrected by these approaches.

Unconventional thinking provides different insights and new ways of looking at old information. Stanton's ideas about synvolcanic origin for certain massive base metal sulphide ores, Darwin's about evolution of species through natural selection and Wegener's about continental drift were examples. All three caused reconsideration and re-evaluation of the established concepts of their time, and prompted a search for new evidence. Their own errors as well as those of the conventional views were thereby revealed. But unconventional ideas represent a challenge to accepted conventionalism which too often seeks to suppress them and to relegate their proponents to scientific obscurity. They must be evaluated on the basis of fact alone, not by comparison with established interpretations, for they will inevitably conflict with the latter.

Earth science is an imperfect attempt to explain, as accurately and completely as possible, the phenomena that have affected the earth as we know it. Conventionalism, through willingness to accept the favoured hypothesis as uniquely and totally correct should be avoided. Unconventional thinking promotes evaluation of multiple hypotheses and thereby contributes to scientific progress. It merits acceptance and recognition, not rejection and suppression.

Introduction

It is a privilege to contribute a paper to this Symposium in honour of a highly respected scientist, colleague and friend, R.L. Stanton, who, during a distinguished career, has contributed significantly through unconventional thinking, to earth science and to the study of mineral deposits.

The natural sciences are intrinsically inexact; less quantifiable, with fewer immutable laws than the physical sciences, and the earth sciences are, perhaps, the least so of all. Quantification in the earth sciences is rendered difficult by its fewer readily measurable parameters, and by the many complex, inter-related and often widely variable factors, themselves fundamentally qualitative, that play a part in the processes that shape the earth. It is additionally complicated by evolutionary changes, both gradual and abrupt, through four billion years of earth history. The results are many interpretive explanations for the causes and processes that have generated observed geological relationships; but too often the most favoured of these is accepted as fact. Unconventional thinking in earth science, therefore; provides an important means toward essential continued re-evaluation of all possible hypotheses.

Unconventional Thinkers and Their Ideas

In the late 1950's R.L. Stanton (1959), one of a handful of workers that included Haddon King in Australia and Christofer Oftedahl (1958) in Norway, challenged the conventional view that volcanogenic massive sulphide (VMS) deposits were structurally controlled and had formed by epigenetic hydrothermal replacement, probably from magmatic fluids that were generated, and derived their dissolved metals during late stages of granitic crystallisation. Hundreds of published papers, theses and studies had shown it to be so. It was orthodoxy. But Stanton's observations of their stratigraphically controlled distribution in volcanic rocks of an early Palaeozoic island arc near Bathurst in the Lachlan Fold Belt of New South Wales led him to an unconventional idea.

In 1956-1958 Stanton also visited North America and observed similar geological relationships and deposits near Bathurst, New Brunswick; an unexplained and fortuitous geological coincidence that, nevertheless, strengthened his views. At that time North America was the "cold bed" of conventionalism on this subject, insofar as "hot beds" and conventionalism are, by definition, mutually exclusive! Stanton suggested, instead, that these deposits were stratigraphically controlled due to their syn-sedimentary origin by a process related to the island arc volcanism that had formed their host rocks. Here indeed, was unconventional thinking! Stratigraphic rather than structural control? Syn-sedimentary rather than epigenetic emplacement? A volcanic rather than granitic affiliation? These ideas were roundly attacked and widely rejected; they were suspect at best, denigrated at worst. Their proponent was labelled an iconoclast; an unreasonable man.

“The reasonable man adapts himself to the world. The unreasonable man persists in trying to adapt the world to himself. Therefore all progress depends on the unreasonable man." G.B. Shaw - appendix on "Reason" *in Man and Superman.*

But the ideas were ahead of their time. It is relevant and interesting to recollect that they preceded, by about a decade, the oceanographic investigation of the sea floor that subsequently and convincingly demonstrated the validity of these ideas.

“It is entirely normal that when an astonishingly new idea comes off somebody's mental assembly line, it will take a while before other people's assembly lines tool up sufficiently to deal with it." Robert Ardry- *The Territorial Imperative.*

It is one thing to observe, measure, and from direct experience on the present sea floor to deduce the nature of the generative processes for these ores. But it was quite another in the late 1950's, reasoning only from the observed geological relationships that reflect the results of both the past generative processes, but also the overprints of multiple and complex later, superimposed processes, to first distinguish the latter from the former and second, by inductive reasoning to deduce and comprehend the ancient ones that formed the ore. The details and complexities of this reasoning however, are not the main issue here; the fundamental impact, significance and reception of a new and unconventional idea are the key points to be considered.

Charles Darwin faced an orthodoxy of a different nature, not so much scientific but broader, perhaps more fundamental for it was societal and rooted in religious belief. Nevertheless, like epigenetic hydrothermal replacement, creation of earth and man in 4004 BC had been established - in this case by careful mathematical calculation. The uncertainties of their discipline render geologists loath to take issue with, even awed by numerical calculations. F.T. Thwaites, a distinguished geomorphologist and Pleistocene geologist at the University of Wisconsin often pointed out, in his lectures in the early 1950's, that numerical calculations are valid and reliable only so far as their underlying assumptions are correct and applicable. His specific wording was "figures don't lie, but liars can figure”.

As in Stanton's case, Darwin's new observations of life forms during his voyage on The Beagle had led him to question the orthodox, conventional view, and it is clear from his own writings that this forced a painful re- evaluation. The latter led to doubt, doubt to disbelief and the disbelief to new insight and an unconventional idea. Evolution of life through natural selection was a radical challenge to creationism, and was hotly opposed by established society of that time. It is still opposed in rare instances today. It is amazing how long the "tooling up" referred to by Ardry sometimes requires, and surprising how long compelling new evidence can be ignored! Early in the 20th century Alfred Wegener, a geographer and climatologist used simple data from these disciplines to formulate and advance the new idea of continental drift. Here again, was inductive reasoning and unconventional thinking! Ignoring politics, a united world - Pangea - was simply attainable by eliminating the oceans and pushing the continents together like a jig saw puzzle. But once again there was a troublesome mathematical and geophysical objection. Sir Harold Jeffery of the Royal Society, calculated the magnitude of the crustal tidal force suggested by Wegener as the possible cause for drifting continents. His results showed that this was a quite impossible explanation, and so the idea was relegated to obscurity. Yet it was not without geological support. On the contrary, it was supported by paleontological evidence of matching lower

Palaeozoic faunal zones on opposite sides of the North Atlantic, by stratigraphic evidence of similarly matching lithostratigraphic sequences, by comparable mineral deposit types and host terranes on opposite margins of the South Atlantic and by paleogeographic and paleoclimatic evidence in the same region. But geophysical orthodoxy of the time used integral calculus - the ultimate confounding argument to geologists - to prove that the earth's crust was simply not pushable! Not by any known process, by anything, by anybody and certainly not by Alfred Wegener who, by this time, was long dead, having left behind a troublesome and unconventional idea to bedevil his successors. The idea was rejected, Wegener labelled a geofantacist. Orthodoxy prevailed until, as in the case of Stanton, mature re- evaluation and new information established the validity of his ideas.

Discussion

All three of these examples share a number of similar elements. The unconventional ideas were subjected to a storm of negative and largely destructive criticism, albeit of differing intensity and from differing sources. They were to varying degrees re1ected, set as1de for years, in some cases and circles even suppressed by conventionalism. Their proponents were ignored at best, excluded from the main stream of scientific dialogue, ridiculed at worst. Conventionalism prevailed, until new evidence and mature re- evaluation led to gradual, then widespread although still not universal acceptance of the unconventional views.

"The obstacles to discovery -the illusions of knowledge - are also part of our story. Only against the forgotten backdrop of the received common sense and myths of their time can we begin to sense the courage, the rashness, the heroic and imaginative thrusts of the great discoverers. They had to battle against the current facts and dogmas of the learned." Daniel J. Boorstin -*The Discoverers*

The fundamental benefits to earth science of these ideas are, in hindsight, abundantly clear. All three advanced new, alternative hypotheses to accepted, conventional, orthodox views. In so doing all offered new innovative insights, new perceptions and understanding, new ways of looking at old evidence. And all identified new dimensions and directions for investigation. These, in turn, prompted the search for additional evidence that would, hopefully, be definitive of one explanation, or would deny another. Thus it was the discovery of magnetic striping in the oceanic crust that finally confirmed Wegener's idea, and it was observations of sea floor hydrothermal discharges from which metallic sulphides were precipitated that finally substantiated Stanton's unconventionalism. The ideas together with this new evidence forced a thorough reconsideration of all data and a mature re-evaluation of fundamental concepts including all possible explanations, tile new and unconventional as well as tile old and orthodox.

"A mind - - - - endowed by nature with the desire to seek, patience to doubt, fondness to meditate, slowness to assert, readiness to reconsider, steadiness to set in order and neither affecting what is new nor admiring what is old and hating all kinds of imposture." Francis Bacon - *The Scientific Mind.*

Bacon's definition emphasises the importance of a measured and mature approach. In earth science this is often lacking in its response to unconventional thinking which is commonly met with one of two undesirable extremes, premature acceptance or premature rejection, the latter much more serious than the former. The danger in premature acceptance arises because a new and unconventional idea is certain to be partly wrong and/or incomplete. It is simply not possible to advance a broad and innovative new hypothesis that includes thorough and comprehensive explanations for all its aspects and ramifications. These develop only from mature study, extensive reconsideration and additional investigation as outlined by Bacon. Darwin himself could not prove the line between man and apes and recognised this deficiency in his theory (Eisley, 1956). And Jeffery's calculation of tile crustal tidal force as inadequate to cause rifting and separation showed Wegener's initial explanation to be incorrect. But neither of these deficiencies, nor their use as bases for broader attacks on the fundamental unconventional theories were sufficient to disprove the latter -they merely questioned (and rightly) specific aspects. There is a useful lesson here; although unconventional ideas must be constructively criticised and evaluated, they should not be prematurely rejected because, when advanced, they fail to explain everything, or because, their explanation for some specific aspect is deficient. It does not necessarily follow that, because they are inadequate or incorrect in one or even a few details, they are more broadly or fundamentally wrong. Instead, they must be judged on their totality considering their ability to explain all, not a few relevant aspects, and in comparison with the similar ability of alternative explanations.

Moreover, tile degree of correctness of an unconventional idea is not its fundamentally most important consideration. Whether right or wrong, or as is so often the case in earth science, partially both, tile new idea forces tile thorough re-evaluation of all alternatives, and the search for new definitive evidence that are the stepping stones toward improved understanding and scientific progress. The degree of validity of the unconventional, as well as that of the conventional view will, ultimately, be determined by these considerations which the former, but not the Iatter induces.

"A scientist has the right to be wrong. It is a right approximating an obligation, for if a scientist becomes more concerned with being right than with expressing the convictions of his judgement, then he violates a public trust." Robert Ardry - *African Genesis.*

Too often earth science rushes to a premature, and therefore faulty judgement in its eagerness to decide between right and wrong. This leads to premature rejection of the unconventional idea, often through on inappropriate, too narrow and too rigid contrast with orthodox conventionalism. But disagreement is inevitable here, as well as healthy. If the accepted view is to be the basis for evaluation of the unconventional one, then the latter is inevitably doomed at the outset to unwarranted, premature rejection and even suppression. Premature rejection is the most serious danger because it perpetuates conventionalism. It prevents the very re- evaluation of all alternatives and the search for new evidence that is the greatest benefit of the unconventional idea. Thus it is a fault that cannot be corrected. At tile other extreme lies premature acceptance of the unconventional idea, often through its too enthusiastic introduction, overly comprehensive application and unjustifiably definite espousal. An undesirable consequence might be termed tile "bandwagon approach, also not uncommon in earth science.

"Getting carried away with a good idea is human, forgivable, perhaps even necessary if anyone is going to listen." Robert Ardry- *The Social Contrad.*

This is the less serious extreme because it will be corrected through tile very re-evaluation of alternative explanations and tile search for new evidence that it, itself, generates; it is self-correcting, not self - perpetuating.

In re-evaluation of all alternative hypotheses it is vitally important to distinguish between fact and interpretation. Fact is real, measured, observed and largely objective, but it is also incomplete and therefore inadequate. Interpretation on the other hand, is perceived or deduced from fact, experience and understanding. It is therefore subjective, partly incorrect and similarly inadequate.

what we KNOW = fact

(but we don't know everything) = incomplete

what we deduce/infer from fact = interpretation

(i.e. what we THINK WE KNOW) = partly incorrect

In evaluating an unconventional idea, facts must be emphasised for they must be explained by any and all hypotheses. But interpretations must be de-emphasised because they are partially incorrect. Moreover, by definition and inevitably, the conventional, orthodox view will conflict and disagree with the new explanation. The former cannot therefore be used as prima facie evidence to disprove or reject tile latter. Moreover the fundamental significance of facts must be logically evaluated. Unfortunately in earth science, groups of facts - or data sets as they are currently designated - are seldom uniquely definitive of a single cause or process. On the contrary, they are commonly explainable by two or even more causes or processes, or more complex still, by combinations of differing processes that were superimposed on one another at different times, like the primary genetic and superimposed later metamorphic characteristics distinguished by Stanton in tile VMS deposits. In such cases the facts are definitive of no single cause or process, but are permissive and equally supportive of two or more. For example, circular shape, fallout debris, raised rims and central uplifts are all characteristics common to both meteoritic impact craters and explosive, subaerial, continental volcanic calderas. In the absence of additional definitive criteria such as active plumes in tile latter, these characteristics are proof of neither but support both equally. Yet they have commonly been interpreted as favouring one or the other, most recently meteoritic impact in both terrestrial and extra-terrestrial geological environments. Many currently favoured geochemical and light stable isotopic data are comparably ambiguous (Patterson et al., 1981; Hutchinson, 1982).

Too often in earth science one explanation is favoured over another that is equally possible, considering the available facts, on the subjective grounds of personal preference, experience or understanding. This lacks scientific objectivity. It is necessary in interpretation of course, to select and prefer the best amongst the alternative possibilities - that which accounts for most of the facts leaving least unexplained. But it is also important to recognise that the preferred explanation remains an interpretation, and to therefore retain the others, perhaps downgrading them, for future reconsideration in the light of new evidence and perceptions.

In all three examples orthodox perceptions and interpretations, not facts alone, were applied to the unconventional ideas. When this occurs, the inevitable resulting conflict and rejection of the unconventional idea tends to convert orthodoxy into dogma. The favoured interpretation thus becomes fixed, dosed, and restricted within defined limits. Dogma is then an inhibitor of, whereas the hypothesis is no longer a means toward, scientific progress.

"The ruling passion, be it what it will, the ruling passion conquers reason still." Alexander Pope - *Epistle to Lord Bathurst.*

Dogma has two main aims. The first is self-protection from dissenting views, which is pursued by their rejection and even suppression, as it was with Galileo who was forced to recant his views by the Inquisition. The second aim is self-propagation and self-perpetuation which are attempted through further substantiation and extension of applicability to demonstrate universality. The means by which both these aims are pursued are serious abuses of scientific method.

Unfortunately, self-protection is commonly pursued by personal attack on proponents of the unconventional. As in the examples, the unconventionalists are ignored at best, outcast from scientific dialogue, ridiculed at worst. Fortunately, threats of physical violence like those directed at Galileo are no longer employed but the effects of scientific ostracism and ridicule may be equally damaging in their psychological consequences, and equally effective in suppression of the idea. In this manner the unconventional views are discredited. They are cast not only as incorrect but as unwelcome and negative, as disruptive and destructive criticism of orthodoxy and of the scientific establishment. They are no longer accepted as positive alternatives aimed at improved understanding. These practices are both a sad injustice to proponents of the ideas and a serious disservice to science itself.

On occasion, the unconventional idea is discounted and discredited on a "popularity" basis. By definition this criticism is a truism, for a new idea can only be advocated by one or a few in comparison to majority support for the conventional view. A multitude of mineral deposits geologists and a myriad of published papers and theses supported the epigenetic hydrothermal replacement hypothesis for origin of VMS deposits when Stanton and a few others advanced their unconventional explanation. Fortunately, truth in earth science, unlike elections, is not decided by majority vote. The popularity argument, although always true, is without scientific merit. It is merely a "safely in numbers" defense of the conventional.

Unfortunately, current evaluation procedures in earth science permit, and even foster the abuses of self-protection and self- propagation. This is possible through peer review rejection of manuscripts submitted for publication, and of applications for research grant funding, by careful screening in selection of invited speakers and of submitted abstracts for scientific conferences, and by bias in academia in the granting of promotion and tenure.

"Conventional peer review has a disturbing potential of preventing publication of highly original, and truly innovative and revolutionary ideas." Teichert - *Peer Review.*

These procedures, although valuable, necessary and the best available, are predisposed toward suppression of the unconventional. Manuscripts, funding applications, invitations and promotion-tenure submissions are commonly directed to established earth scientists in the relevant fields as referees. But these referees represent the conventional views, have in many instances published on, and helped shape them. To a considerable and undesirable degree this sets the fox to guard the chickens! It places a scientific and ethical obligation on referees to act with thorough objectivi1 and impartiality. Clearly, this is impossible to achieve totally because scientists, as individuals, are subject to the full gamut of human failings. Nevertheless the obligation of a referee must not be ignored or taken lightly. Criticism must be constructive and positive not destructive and negative. It should emphasise factual content, reliability, adequacy and presentation but should not focus on interpretation, for here disagreement is inevitable and desirable. A sincere effort toward objective and impartial judgment, free c personal bias, opinion and preference, is mandatory. Referees should seek and recognise innovative new ideas and directions, not reject or suppress them on grounds of their personal views. If these requirements cannot, in full conscience be met, then the request to review should be declined. It would promote objectivity an impartiality if reviewers routinely identified themselves to author and applicants (Teichert, 1989).

Self-propagation and self-perpetuation have equally undesirable consequences in earth science by trivialising research, so Research turns inward and becomes self-centred, concerned with its own rightness, self-justification. It seeks to further validate what ho already been demonstrated and recognised. In order to confirm the conventional, it applies similar approaches and data to more and more examples, and in ever greater detail. The broad, fundamental issues become obscured, lost sight of, in a mass of often multi-interpretable data. New insights and directions in research or thereby inhibited, and scientific progress is retarded.

"Science, after all, is fundamentally about process learning why and how things happen is the soul of our discipline. You can't abandon the search for cause in favour of a dry documentation of pattern. You must take risks of uncertainly in order to probe the deeper questions, rather than stopping with sterile security." Stephen Jay Gould - *Darwinism defined: the distinction between fact and theory.*

In this work, Gould explores the important distinction between fact and theory that is emphasised above, and in this quote he also cites the risks of uncertainly - the probability of being wrong, at least in part. As previously discussed, this must be accepted, for the alternative is unthinkable!

To escape criticism

- do nothing

- say nothing

- be nothing" Elburt Hubbard

<u>Additional Unconventional Possibilities</u>

The most rewarding and stimulating benefits of unconventional thinking are the new insights that it provides, the new ways of looking at things that it offers and the resulting enlightenment that it casts. Perhaps the ideas of Darwin on evolutionary change, or Wegener on global tectonics and of Stanton on the origin of VMS deposits have not yet been directed down all the possible avenue along which they may be signposts and which they might elucidate. The new global tectonics hove revolutionised earth science an provided an invaluable extension and elaboration of Wegener's unconventional idea. But, as may be inevitable in all scientific thinking, they have developed a dogma of their own. Thus, current orthodoxy in new global tectonic theory attempts to apply modern tectonic mechanisms and processes, as measured and recognised on present plate boundaries, directly to the ancient Archean earth. But is this logical? Or do the modern ones instead, point the way back in time through a long sequence of evolutionary changes in tectonic processes toward those of Archean time, the sequential change culminating in those of the modern earth? To pose the question in Uniformitarian terms, is the present a key -or is it identical -to the past? The two concepts are fundamentally different.

The essence of Darwinism is evolutionary change, in the case he studied of earth's life forms through natural selection. But geology provides evidence of similar time-dependant changes in earth's atmosphere and hydrosphere (Holland, 1978; Cloud, 1968), and in its ore deposits and ore-forming processes (Hutchinson, 1981).

What changes then, may have occurred through 4 billion years in the thickness and composition of the earth's crust, mantle and core; and in its temperature and heat flow? Has it heated or cooled? These basic parameters govern tectonic processes. Did the earth expand, as Carey - another unconventional thinker - suggested (1976), and if so, when? Global expansion in mid-Proterozoic, rather than in Permo-Triassic time, might accommodate both Carey's evidence and that of the new global tectonics, and might also explain some enigmatic aspects of mid-Proterozoic geology (Hutchinson, 1981).

Stanton's ideas about sea floor metal deposition open some new directions for investigation. In addition to their high content of the base metals, most VMS deposits contain many other metals including gold and silver, felsic-affiliated tin and tungsten, mafic- affiliated cobalt, nickel and chromium. Their ubiquitous presence albeit usually in minor amounts, is simple but compelling evidence that all these metals too, are mobilised by, transported in and deposited from the same generative sea floor hydrothermal fluids that form these ores.

Orthodoxy holds that tin deposits are uniquely related to the crystallisation and fractionation of $-type, or ilmenite-series granites. Yet granites of any kind are lacking during formation of the tin- enriched VMS deposits, one of which, Neves-Corvo in Portugal, contains 2.7 million tonnes of ore grading 2.8% tin within a much larger orebody of 32 million tonnes grading 8.5% copper (Tin International, 1989). Moreover tin, in amounts greater than 0.15%, has recently been found in samples of both sulphidic sediment and polymetallic massive sulphide from the outer wall of a sulphide chimney, all dredged from a large body of pyrrhotite-rich massive sulphide on the sediment-covered floor of the Escanaba Trough of the southern Gorda Ridge in the east Pacific ocean (Koski et al., 1988). In this setting too, needless to say, granite of either S-, or any other type is absent; yet tin has been enriched, apparently in this case by extensive sub-sea floor interaction between turbiditic sediment and evolved hydrothermal fluid. This new evidence indicates a need for revision of the orthodox view concerning formation of tin deposits. The current understanding must be broadened to accommodate both early, syn-sedimentary sea floor hydrothermal stages and processes of tin enrichment, in addition to the well documented later ones of granitic activity. Additional studies may show that both, not one or the other, are essential aspects of tin metallogeny and the development of the world's great tin fields. And it will identify the criteria that permit distinction between deposits formed by the differing processes during the two stages, as well as those that result from superimposition of the later on the earlier processes.

Analogous considerations apply to the presence of gold, nickel and chromium in VMS deposits. The particular conditions of fluid chemistry and processes in sea floor hydrothermal systems by which these elements are carried, and might be enriched to profitably mineable levels are potentially fruitful fields for research. This would provide new insights into the origin and metallogeny of their ores, and perhaps require a broadening of current orthodox views.

All greenstone-hosted gold lodes are currently interpreted as structurally controlled, and of epigenetic metamorphogenic origin (Colvine et al., 1988; Groves and Phillips, 1987). And the uniquely magmatic generation of nickel sulphide and chromite deposits has been orthodoxy for decades. Tale-carbonate rock closely associated with the many of the gold, nickel and chromite deposits has been considered uniquely as an alteration product of their ultramafic host rocks, thereby confirming their ma9_matic origin. Yet it has been suggested that a few sediment-affiliated nickel occurrences in ferruginous sedimentary rocks (Candela et al., 1990), as well as some sediment-affiliated ones of the komatiite-hosted type (Robinson and Hutchinson, 1982; Bavinton, 1981; lusk, 1976), and also rare chromite deposits like Selukwe, Zimbabwe (Cotterill, 1969) are not readily explainable by these conventional views. Moreover, talc occurs in the footwall of the Matagami Lake VMS orebody (Costa et al., 1983), and has been recently recognised in sea floor hydrothermal deposits of the Guaymas Basin (Koski et al., 1985) and the Escanaba Trough (Koski et al., 1988) where ultramafic rocks are absent. Clearly, the presence of talc is not uniquely definitive of the ultramafic intrusive environment. Considering this, the conventional views concerning the origin of some of the gold, nickel and chromite deposits must be broadened, and alternative and unconventional possible role of sea hydrothermal processes in forming them must be considered.

Recently Stanton has applied new understandings of hydrothermal alteration processes and effects in VMS deposits to advance an innovative and controversial interpretation of the conventional Borrovian regional metamorphic sequence (Stanton, 1989). As in the case of his earlier VMS work, this has been less than enthusiastically received. Some of the same abuses have followed. But the new interpretation, right, wrong or portly both, integrates hydrothermal metasomatic processes with regional metomorphic ones in a manner that offers new insights and directions of investigation in both these fields. The ideas might provide improved understanding of both the complex, controversial and highly metamorphosed deposits of the Broken Hill field in New Wales. It merits thorough consideration and prompts re-evaluation of both the new and old ideas.

Summary and Conclusion

Earth science is on attempt to explain, as accurately and completely as possible, the phenomena that have affected and shaped the earth as we know it. But we know it imperfectly and the explanations are therefore only partly correct. It is immensely broad, embodying its own many specialisations as well as those of other sciences. It is four-dimensional and especially concerned with evolutionary changes through time. Consequently it is mainly qualitative; less amenable than some other sciences to measure and quantification.

It must therefore remain open to questioning and re-evaluation to accommodate new concepts, insights and evidence. Conventional thinking serves this requirement inadequately, especially when it is converted to orthodoxy and ultimately to dogma it in scientific progress and is an abuse of scientific method. The new advances in earth science hove come not from conventionalism, but increasingly detailed studies of what is already largely understood but from unconventional, new and innovative ideas, and from new data that they generate by the thorough re-evaluation they prompt. And not infrequently they come from non-professionals.

"No matter how far back we go in the history of science seems that an extraordinary number of great discoveries · made by dilettantes, amateurs, outsiders-the self-taught were driven by an obsessive idea, unequipped with the brains of professional training and the blinkers worn by the specialist so that they were able to leap over the hurdles set under academic tradition." C.W. Ceram (Moree) -*Gods, Graves and Scholars.*

Briefly stated, "left lateral leaps" in geological thinking are valuable. Such new ideas however, are inevitably controvercial partly erroneous and incomplete but should not be prematurely discarded on these grounds.

Unconventionalism is to be fostered and encouraged, not rejected and suppressed. Its proponents merit recognition and acceptance, not discouragement and ostracism. Unconventional thinking is essential for major new advances and improved understanding in earth science. It forces re-evaluation of many alternative hypotheses and points the way toward the search for new evidence. Its very advancement, not its validity, error or demand thereof is the true merit of unconventionalism.

"Be thou the first true merit to befriend. His praise is lost waits 'til all commend." Alexander Pope - *An Essay on Criticism.*

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References

Bavinton, O.A., 1981, The nature of sulfidic metasediments at Kambalda and their broad relationship with associated ultramafic rocks and nickel ores: Econ Geo/, v76, p1606-1628.

Candela, P.A., Wylie, A.G. and Burke, T.M., 1989, Genesis of the Ultramafic, Rock-Associated Fe-Cu-Co-Zn-Ni Deposits of the Sykesville District, Maryland Piedmont: Econ Geol, v84, no3, p663-675.

Carey, W.S., 1976, The Expanding Earth: Developments in Geotectonics 10, Elsevier Sci Pub Co, 488p.

Cloud, P., 1968, Atmospheric and hydrospheric evolution on the primitive earth: Science, v160, p729-736.

Colvine, A.C., Fyon, J.A., Heather, K.B., Marmont, S., Smith, P.M. and Troop, D.G., 1988, Archean Lode Gold Deposits in Ontario: Ontario Geological Survey Mise Paper 139, 136p.

Costa, U.R., Barnett, R.L. and Kerrich, R., 1983, The Mattagami lake Mine Archean Zn-Cu sulfide deposit, Quebec:hydrothermal co-precipitation of talc and sulfides in a sea-floor brine pool - evidence from geochemistry and mineral chemistry: Econ Geol, v78, p1144-1203.

Cotterill, P., 1969, The chromite deposits of Selukwe, Rhodesia: in Wilson, H.D.B., ed, Magmatic Ore Deposits: Econ Geol Mono 4, p154-186.

Eisley, L.C., 1956, Charles Darwin: in Gingrich, 0., ed, Scientific Genius and Creativity: Readings from Scientific American, New York, W.H. Freeman and Co, p67-75.

Groves, D.l. and Phillips, G.N, 1987, The genesis and tectonic control on Archean gold deposits of the western Australian shield - a metamorphic replacement model: Ore Geology Reviews, v2, p287-322.

Holland, H.D., 1978, The Chemistry of the Atmosphere and Oceans: New York, John Wiley and Sons, 351p.

Hutchinson, R.W., 1981, Mineral deposits as guides to supracru evolution: in O'Connell, R. and Fyfe, W.S., ed, Evolution of Earth: AGU-GSA Geodynamics Series, 5, p120-140. Hutchinson, R.W., 1982, Discussion: Geologic setting and gen of cassiterite-sulfide mineralization at Renison Bell, West Tasmania: Econ Geol, vll, p199-202.

Koski, R.A., Lonsdale, P.F., Shanks, W.C., Berndt, M.E. and Howe, S.S., 1985, Mineralogy and Geochemistry of a Sediment-Has Hydrothermal Sulfide Deposit from the Southern Trough Guaymas Basin, Gulf of California: Jour of Geophysical Research v90, noB8, p6695-6707.

Koski, R.A., Shanks, W.C. Ill, Bohrson, W.A. and Oscarson, R 1988, The composition of massive sulfide deposits from sediment-covered floor of the Escanaba Trough, Gorda Rid implications for depositional processes: Can Mineralogist, v p655-673.

Lusk, J., 1976, A possible volcanic-exhalative origin for lentiCL nickel sulfide deposits of volcanic affiliation, with special reference those in Western Australia: Can Jour Earth Sci, v13, p451-458. Oftedahl, C., 1958, A theory of exhalative-sedimentary ores: G Foren Stockholm Forh, v80, Pt1, no492, p1-19.

Patterson, D.J., Ohmoto, H. and Solomon, M., 1981, Geological setting and genesis of cassiterite-sulfide mineralization at Renison Bell, Western Tasmania: Econ Geol, v76, p393-438.

Robinson, D.J. and Hutchinson, R.W., 1982, Evidence for volcangenic-exhalative origin of a massive nickel sulphide deposit Redstone, Timmins, Ontario: in Hutchinson, R.W., Spence, C and Franklin, J.M., ed, Precambrian Sulphide Deposits, H Robinson Memorial Volume: Geol Assoc Can Spec Paper : p211-254.

Stanton, R.L., 1959, Mineralogical features and possible mode emplacement of the Brunswick Mining and Smelting orebodies, Gloucester County, New Brunswick: Can lnst Min and Metal/ B v52, no570, p631-643.

Stanton, R.L., 1989, The precursor principal and the possible significance of stratiform ores and related chemical sediments in the elucidation of processes of regional metamorphic mine formation: Phil Trans Royal Soc, London, A 328, p529-646. Teichert, C., 1989, Peer Review: Geology, v17, p1067. Tin International, Go ahead for Portuguese Mine, January, 1989. p4.

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