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Research Article

Summary of the Nature and Contents of "The Origin of Rocks and Mineral Deposits – Using Current Physical Chemistry of Small Particle Systems"

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Abstract. The book referred to in this title is a comprehensive interdisciplinary scientific treatise that introduces revolutionary new knowledge achieved by competent use of the scientific method. The research on which it is based has been more thoroughly and critically reviewed than is usual for scientific works and the international edition has recently been published.
However, correct statements and advertising of the publisher and booksellers are disbelieved because many scientists assume the author is claiming to have discovered the origin of rocks and mineral deposits. Millions of dollars are spent each year on research endeavouring to understand the formation of ore deposits. It is a preposterous misconception that any one scientist could discover the origin of rocks and mineral deposits.
The book definitely does not introduce a new geological theory or revise an existing one. Using the basic scientific method of logical conclusions from direct observation it reinterprets geological phenomena and processes using currently established physical chemistry of small particle systems. The title of this book *"The Origin of Rocks and Mineral Deposits – using current physical chemistry of small particle systems"*[1] is not a boastful or exaggerated claim. It summarises the results of over 50 years of systematic industrial research that actually achieved an understanding of how modern surface chemistry now explains the otherwise puzzling features and textures we see preserved in the rocks and the release of ore minerals in various geological environments. It is the culmination of the work of many outstanding scientists guiding and mentoring a highly competent and successful mineral exploration team.

THE OUTSTANDING SCIENTISTS

Professor A. E. Alexander

Professor of Physical Chemistry, University of Sydney, 1957 to 1970,

Co-author, Alexander and Johnson, *"Colloid Science"*, 1950, Oxford University Press.

He identified mysterious large banded chert nodules in specimens of porphyroid from the Black Angel prospect in Tennant Creek as colloidal accretions in 1959. This initiated the many years of research into the origin of mineral deposits based on the properties and behaviour of colloidal particles in natural sediments.

Professor P. G. H. Boswell

No picture is available of Professor P. G. H. Boswell, OBE, Geology Department, Liverpool University, UK. He is the author of *"Muddy Sediments"*, Heffer, Cambridge, 1961. Professor David Williams from Imperial College in London presented this book to Geopeko after his visit to Tennant Creek in 1962. It was our first authoritative introduction to the rheological and surface properties of natural sediments.

Dr Ralph K. Iler

We have no picture of Dr Ralph K. Iler, of DuPont de Nemours & Co, Wilmington, Delaware, USA. After several brief consultations during his visit to Australia in 1984, his comprehensive treatise *"The Chemistry of Silica"*, John Wiley and Sons, New York, 1979, provided the essential information on the solubility, polymerisation, and surface properties of silica particles in natural sediments.

The late Professor S. W. Carey

The late Professor S. W. Carey, AO, DSc, (1911-2002) was certainly the most highly qualified Earth scientist in Australia in recent times. His qualifications include two Honorary Doctorates, Fellow of Australian Academy of Science, Honorary Life Fellow of seven learned societies, five medallists and numerous Chairmanships and Presidencies. After his first visit to Tennant Creek in 1962 he recognised the significance of Geopeko exploration company research and immediately convened an international symposium at the University of Tasmania with field visits to Tennant Creek entitled *"Syntaphral Tectonics and Diagenesis"*[2]. This was to create wider interest in understanding how the physical chemistry of small particle systems now explains so many otherwise puzzling geological phenomena. Professor Carey became guide and mentor to this series of ongoing research projects until he died in 2002.

The late Professor T. F. W. Barth

Professor T. F. W. Barth from Oslo University in Norway was a visiting Fellow to the Australian Academy of Science in 1965. He is the author of several books including *"Theoretical Petrology"*, John Wiley & Sons, New York, 1962, and *"Feldspars"*, John Wiley & Sons, New York, 1969.

With some difficulty, Professor Carey prevailed on Professor J. C. Jaeger, member of the Australian Academy of Science at that time to alter Professor Barth's schedule of visits to Australian universities so the he could accept Sir John Proud's invitation to visit Tennant Creek. Professor Barth accepted and arrived in Tennant Creek on the afternoon plane of Monday 8th November 1965.

Professor Carey had arrived two days earlier to assist in hosting the visit of this world authority on feldspars. It was a busy but very successful visit. Professor Barth was at first rather reserved about the way our new approach using principles of current colloid and surface chemistry seemed to explain so much. However, after a week inspecting mines, drill cores, outcrops, and in-depth discussions and technical presentations each evening, he became keenly interested and enthusiastic. On the evening prior to his departure from Tennant Creek, Professor Barth's remark became a legend in company history and a turning point for Geopeko exploration and research. In his best Norwegian accent he said:

> *They told me in Canberra I was coming on a wild goose chase, but now I know where the gooses are!*

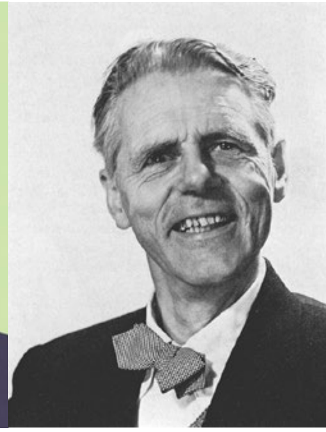
Professor T. F. W. Barth was on the organising committee of the International Geological Congress and recognising the importance of Geopeko research he invited papers to be presented at the 23rd International Geological Congress in Prague in August 1968. By 1968, the application of advanced geophysics and understanding the origin of the mineral deposits had found and brought into production four new mines at Tennant Creek and Geopeko drilling had located high-grade mineralisation at the Explorer 1 prospect that was to become the Gecko Mine. These successes justified a three-month trip to Europe for John Elliston and his wife to present the invited papers prepared for the 23rd IGC and to visit mines prospects and outcrops on the pre and post Congress excursions.

Professor Zdenék Pouba

Professor Zdenék Pouba from Charles University in Prague led the pre-Congress excursion to the Silesian mines in Poland. The Congress opened in grand style with some 5,000 delegates on Monday 19th August 1968 and the first paper entitled *"Retextured Sediments"*[3] was successfully presented. The more important paper *"The*


Professor A. E. Alexander


The late Professor S. W. Carey


The late Professor T. F. W. Barth


Professor Zdenék Pouba


Professor Richard L. Stanton


Distinguished Professor Ross Large


Emeritus Professor Thomas W. Healy


Sir John Proud

genesis of some epigenetic type ore deposits" was scheduled for presentation later in the congress. However, the Russians invaded Czechoslovakia and their tanks arrived in Prague in the early hours of Wednesday 21st August. Congress was disrupted and abandoned. Professor Pouba arranged the evacuation from Prague and recognising the significance of the new research in *"The genesis of some epigenetic type ore deposits"*, he had this paper published by the Czech Geological Society (Organ. Czech. Soc. of Min. and Geol., 14(2): 129-139.). He found that the Russian authorities would not permit return of Congress manuscripts that had not been presented for them to be published elsewhere.

Professor Richard L. Stanton

Professor Richard Stanton was head of the Geology Department, University of New England, Armidale, NSW. His very significant and fundamental research is completely independent of the industrial research projects that have established the origin of rocks and mineral deposits. He corresponded for some years pointing out its complimentary nature and confirmation of the origin rocks and mineral deposit using the physical chemistry of small particle systems.

In 1989, Professor Stanton concluded that a wide range of metamorphic, gneissic and porphyry-like rocks had developed their texture by crystallisation of ordered sedimentary diagenetic gels [Stanton, R. L., *"The precursor principle"*, 1989, Phil. Trans. Royal Society of London, A 328: 529-646 (p. 638)]. His conclusions are based on mineralogy and direct measurement of the chemical composition of the substances crystallising with a microprobe analyser. Stanton's establishment of the precursor principle agreed with and confirmed the conclusions reached in the systematic investigation of the origin of rocks and mineral deposits using the physical chemistry of small particle systems.

Distinguished Professor Ross Large

Ross Large is a Distinguished Professor of Economic Geology at the University of Tasmania. He was the foundation Director of the Australian Research Council Centre of Excellence in Ore Deposits (CODES). He joined the University of Tasmania in 1984 and was the Director of CODES for over 20 years until recent retirement. Prior to his work at the University of Tasmania Ross large worked for Geopeko in the Northern Territory, gained his PhD at the University of New England in 1973, undertook a Post Doctoral Fellowship at the University of Toronto in 1974 and worked for Geopeko in the difficult to access area at Elliot Bay south of Macquarie Harbour in Tasmania.

Together with Kim Wright, former General Manager, Earth Resources Foundation, University of Sydney, Ross Large organised the highly successful symposium *"Syntaphral Tectonics and Diagenesis – 44 years on"* at CODES in November 2007. The Australian preview edition of *"The Origin of Rocks and Mineral Deposits – using current physical chemistry of small particle systems"* was printed for that occasion and discussion, presentations and papers contributed recognised the exciting new knowledge it contained.

Emeritus Professor Thomas W. Healy

Thomas W. Healy, AO, FRACI, FAA, FTSE, Emeritus Professor Physical Chemistry at the University of Melbourne is a world leader in colloid science. During the period from 1991 to 1999 he was Director of the Advanced Mineral Products Special Research Centre of the Australian Research Council (ARC), and in 2000 was appointed Deputy Director of the Particulate Fluids Processing Centre, also a Special Research Centre of the ARC.

He was consultant to Geopeko Limited from 1967 to 1977. He attended the company technical seminars and provided the essential guidance and information to ensure our application of the physical chemistry of small particle systems and nanotechnology to interpret geological phenomena was correct. He wrote 14 reports for the company the most comprehensive of which is *"Physicochemical Processes in the Diagenesis of Sediments"*, April 1972. He attended and contributed to the symposium *"Syntaphral Tectonics and Diagenesis – 44 years on"* in Hobart in November 2007. His review of the preview edition of *"The Origin of Rocks and Mineral Deposits"* contains the statement **"The colloid science in the book is impeccably correct."** Other leading colloid scientists in Australia who have examined the preview edition, Associate Professor Robert J. Hunter, University of Sydney and Emeritus Professor Barry W. Ninham, Australian National University, agree.

Sir John Proud

John Seymore Proud, a mining engineer, joined the board of Peko (Tennant Creek) Gold Mines NL on 26th September 1952. The company changed its name to Peko Mines NL in 1954 and John Proud became Chairman of the Board and CEO when the company merged with the Newcastle Wallsend Coal Company to become Peko-Wallsend Limited in 1961. John Proud set up the subsidiary company, Geopeko Limited later that year and appointed John Elliston, as Managing Geologist to develop much needed additional resources to sustain operations. Ore reserves at the small Peko Mine were rapidly depleting.

John Proud consistently supported maximum exploration effort and encouraged the research and development of more advanced technologies to achieve it. Geopeko's exploration was highly successful. Five new mines were developed on the Tennant Creek field from the first 15 prospects drilled. By 1975 significant new resources had also been discovered at King Island in Tasmania, the Ranger uranium deposits in the Alligator Rivers Province and prospective economic mineralisation identified at Parkes in NSW. A management consultant firm was commissioned by one of Geopeko's competitors to make a comparative study of the results of 13 successful Australian exploration companies in the period 1960 to 1975. By application of a developing understanding of the way that mineral deposits are formed Geopeko's expenditure on exploration (including substantial expenditure on research) was found to be 320% more cost effective. This record remains unsurpassed and is due to Sir John Proud's support and encouragement for research and technological development.

THE SCIENTISTS AND LEADERS OF AUSTRALIA'S MOST SUCCESSFUL EXPLORATION TEAM

Mr Lewis A. Richardson

Lew Richardson worked on the Tennant creek field for the Australian Geological and Geophysical Survey of Northern Australia in 1936 to 1939. He had done the detailed magnetic surveys of a number of the mines and prospects on the field including Peko, Black Angel, Orlando and the 'Mantle-piece Anomaly' (later to become the Juno Mine). He was geophysical consultant to Peko Mines NL, Peko-Wallsend and Geopeko Limited from 1954 until he died in 1971.

He was meticulous and accurate. He developed a technique for accurately modelling the buried bodies of mineralisation that gave rise to the magnetic anomalies measured on the surface. Patiently with mechanical hand calculators he modelled them as having elliptical shapes with variable axial inclination and dimension. The Peko magnetic anomaly was pear shaped. In 1961 mining and drilling had revealed the shape, dimensions and magnetic susceptibility of the main mineral body. Lew Richardson subtracted the effect of this magnetic body from the larger pear-shaped anomaly he had measured in 1936 to reveal the Peko No. 2 mineral body. Under ground drilling defined ore lenses in this body that extended mine life by about five years. Lew Richardson's modelling of the small rich magnetic body that was to become the Juno Mine predicted within 2 feet where the discovery drill hole would enter this mineral body centred 600ft below the surface.

Mr John Love

John Love was a keen and enthusiastic observer and properly sceptical of the new concepts our research into the origin of the Tennant Creek porphyroids, granites and mineral deposits was establishing. He satisfied himself that our conclusions were correct based on the evidence for that field but represented such a radical departure from mainstream beliefs and teaching that he needed to ensure that they also applied to rocks and mineral deposits world-wide.

He therefore took unpaid leave from Geopeko for a two-year working tour round the world. From South Africa he sent back pictures of orbicular norite he had found in drill core at the Empress Nickel Mine in Gatooma, granite orbicules from Diana's Pool, Lundi River, Zimbabwe, accretions in the colloidal mud from a settling tank at the Nababeep Mine, South Africa, numerous pictures of the fluid folding and structures in the nearby Reitberg Granite, and matching patterns in fluid mud from the tank at Nababeep that he had been able to produce. While in Europe John Love visited the French Academy of Science in Paris to see the fossil echinoderm shell embedded in granite feldspar that Termier and Termier[4] had reported from the Atlas Mountains in Morocco. He studied the 'marker argillite' horizon in British Columbia. This is a narrow band of micro-granite in a sequence of thin sedimentary beds that extend over 100 miles. John Love[5] very carefully checked the petrology and wrote a paper about this granite crystallised from a sedimentary layer for Geoscript on his return. John Love was one of Geopeko's outstanding scientists.

Mr Alex Taube

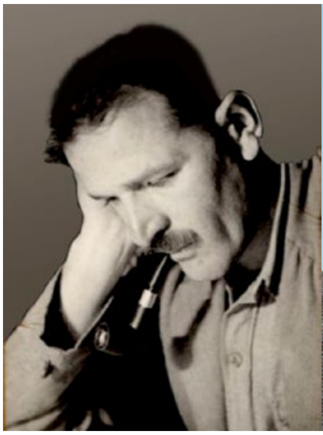
Alex Taube was an outspoken critic of Geopeko research. He stoutly upheld classical volcanogenic models of mineral deposit genesis and loudly demanded extended and costly diamond drill hole patterns based on this model. His scepticism was of the right sort. He could not change his views based on observation of narrow carbonate dykes or ptygmatic quartz veins that he found in the Woodcutters drill core but after some years he became convinced that granite and related porphyroidal and metamorphic rocks had crystallised from hydrous precursor sedimentary pastes or "magmas" in its original meaning. Alex Taube was convinced by his own observation of a substantial limestone breccia dyke that was found within the large Ravenswood Granite Batholith some 2 kilometres from is boundary contact with surrounding rocks.

Mr Geoff Sherrington

Geoff Sherrington was Geopeko's Chief Geochemist. He designed and used a radon detection system for uranium exploration but his main contribution to Geopeko's exploration success was the monitoring system he set up for trace element detection, field sampling and assays. In mineral exploration the decision to continue investigating or follow up a higher geochemical reading often depends a single analytical result. The sample recording and assay monitoring system set up by Geoff Sherrington made a significant contribution to Geopeko's success in calculating ore reserves and developing new resources.

Mr Robert L. Richardson

Bob Richardson continued as company geophysicist in charge of L.A. Richardson Associates after his father died in January 1971. That consultancy was acquired by Peko-Wallsend on 7th November 1978 and Bob became Geopeko's Chief Geophysicist. Meanwhile he and his associates (Mike Palmer, Bruce Kirkpatrick and Albert Berkavicious) had designed, tested and flown in the Alligator Rivers province the world's first 256-channel airborne radiometric survey system for uranium exploration. They located many other uranium anomalies but drilling established very significant energy resources at

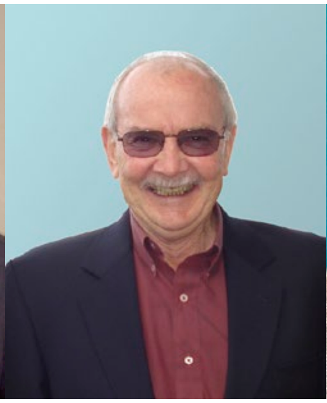

Mr Lewis A. Richardson


Mr John Love


Mr Alex Taube


Mr Geoff Sherrington


Mr Robert L. Richardson


Mr Brian Williams


Mr Rado Jacob Rebek


Mr George Roy Ryan


Mr Kim Wright

Ranger 68 before the Whitlam government policies had quashed Australia's opportunity to develop safe nuclear power generation. This was to be an alternative to the inherently unsafe light water reactors. Bob Richardson also designed a down-hole magnetic survey instrument and a vehicle mounted magnetometer.

When it became clear that the Australian government would no longer permit proper development of its nuclear energy resources, Bob Richardson offered his new aerial survey system for a national geophysical survey in Iran. Mohammad Reza Shah Pahlavi's policy at the time was: - *"We will buy the best technologies that the west can supply to secure this country's economic future when oil resources are depleted."* A US$16 million contract was successfully negotiated and Austirex Aerial Surveys Pty Ltd was set up as a subsidiary company of Geopeko to conduct an aerial geophysical survey of about one third of Iran. Work commenced on 17th June 1977.

Bob Richardson appointed the manager and technical staff and this survey was 85% complete when operations were disrupted by the revolution in Iran in December 1978. Aircraft, aircrews, Australian staff and copies of the data tapes recording the survey results were evacuated and successfully returned to Australia. Substantial financial losses were incurred by the cessation of work at this stage. However, maps were delivered in batches in response to very slow payments. Austirex finally recovered all but about A$1 million of the payments due for 85% of the work. This achieved a breakeven position but an impatient new Peko-Wallsend CEO abandoned collection of the million dollars that would have been profit. He terminated map deliveries and the recovery process. Bob Richardson had left Geopeko but he deserves great credit for his outstanding service to that company.

Mr Brian Williams

Brian Williams remained in charge of exploration and mine geology at Tennant Creek when other senior staff had moved to the new Geopeko headquarters in Merriwa Street, Gordon, in 1972. He did not report the discovery of high-grade gold ore at the Warrego Mine in August 1972 but he was also responsible for the continuing program of testing magnetic anomalies. He was promoted to Managing Geologist, Western Australia in 1975. He set up the field camp at Paterson range and supervised Western Australian exploration. He found oolites in the siliceous shale at the Explorer 12 prospect and large feldspars in the layered granite at Wilson's Promontory that contributed to Geopeko research.

Mr Rado Jacob Rebek

Jacob Rebek has given strong support for the extension of Geopeko research to establish that the basic principles are relevant to all geological environments and to mineral deposits generally. The management of CRA Exploration Limited and Sir Roderick Carnegie, Chairman of their parent company board at the time, commissioned management consultants, McKinsey & Company, Inc., New York, in 1975 to compare the results of 13 successful exploration companies in the period 1960 to 1975. The report identified Geopeko Limited as most successful and its exploration more cost effective that the average of the 13 successful companies by 320%.

This led to an offer of a confidential research contract after John Elliston had retired from Peko-Wallsend in 1984. The contract offered all facilities needed to complete the research and bring the CRAE exploration team "up to speed". Jacob Rebek was assigned the task of supervising the contract, ensuring results were valid and that their application could lead to improved success rates. He examined all progress reports, arranged visits to mines, exploration camps and drilling and study of outcrops. He recognised the importance of the research and its application to significantly improve exploration success rates. He became an enthusiastic supporter. He was promoted to Group Chief Geologist, Rio-Tinto Exploration Limited and after the CRAE-Rio Tinto research contract had finished he arranged a lecture tour to introduce the new concepts to the company's exploration geologists in Chile.

Mr George Roy Ryan

Rob Ryan worked for Peko Mines NL and Geopeko as mine geologist and for resource evaluation from 1959 to April 1962. His work was excellent but he left to join the Geological Survey in Western Australia as Party Leader for the Regional Mapping Division in the Pilbara district. He re-joined Geopeko in January 1966 as Managing Geologist to take charge of exploration in northern Australia. He established a base in Darwin from which they supervised the drilling at Woodcutters silver-lead deposit, did the mine geology at the Mount Bundey iron ore mine and exploration at Eva Valley and Brocks Creek. Early in 1969 Geopeko reconnaissance found uranium ore veins (pitchblende) in crystalline rocks of the Nanambu Complex north of the Oenpelli track and west of the South Alligator River. It indicated that the uranium mineralisation was related to disturbance of the uranium-bearing black shales of Nanambu age and not "unconformity related" as proposed by the official government surveys.

With our joint venture partner's agreement Rob Ryan applied for and was granted a very large exploration area extending westward from the Kombolgie Escarpment to the South Alligator River. Grey soil plains and light tropical vegetation largely cover this vast area but the Ranger radiometric anomaly was easily detected by the airborne total count scintillometer surveys in use at that time. Rob Ryan pegged the Ranger uranium deposit just before the wet season prevented access to that remote area in late 1969. He established a field camp and airstrip at Jabaru in 1970 and assembled a highly competent team of geologists and support staff, including Peter Kitto, Geoff Eupene, Mike Danielson and Andy Browne, to develop one of Australia's most significant energy resources. The Ranger 1 deposit was ready for production in 1972. Rob Ryan is one of the best exploration geologists in Australia.

Mr Kim Wright

Kim Wright joined Geopeko in June 1962 to continue work as mine geologist. He is a keen observer and over his first few years he collected an abundance of evidence that the ore and gangue minerals at Peko had been deposited from colloidal particles dispersed in the ore-forming brines. Kim Wright was responsible for the Peko underground drilling that that developed the No. 2 Orebody and associated ore lenses. His work on the Tennant Creek field found the features produced by unconsolidated sediment movements at the Plum Mine about 12 miles east of Peko. He presented a paper at the 1963 symposium recording these pelletoid, accretionary and concretionary structures. Kim Wright also presented a paper at the Meeting on Remobilization of Ores and Minerals convened by Professor Zaffardi at Cagliari University in 1969. Kim's paper[6] contained magnificent examples of colloform textures and evidence that minerals from the Gecko, Peko, Juno and Ivanhoe Mines had been deposited as a paste or sludge of colloidal precipitate. Kim Wright's work at Tennant Creek also included the development and mine geology of the Ivanhoe Mine.

He was promoted to Managing Geologist, Eastern Australia and moved to Sydney to organise building of the Geopeko headquarters in Merriwa Street, Gordon from which our geophysical, geochemical and ore reserve computation services could be supplied to all exploration bases. This was completed in 1973 and Kim was responsible for Geopeko exploration bases at King Island, Mount Morgan, the coal exploration team at Newcastle in 1971 and at Parkes in 1972. He established a new base at Devonport in Tasmania in 1973 and appointed Ross Large to run it. He set up a base in Townsville in 1974. He and his coal geologist, Paul LeMessurier, found a ptygmatic quartz vein in the coal seam at Pelton. He supervised the development of the Dolphin and Bold Head mines on King Island and Gary Jones successful exploration and development of the North Parkes porphyry copper mine. Kim Wright was one of Geopeko's keenest observers and competent exploration managers.

The idea that any one scientist could claim to have discovered the real origin of rocks and mineral deposits cannot be used to disregard the evidence presented in "The Origin of Rocks and Mineral Deposits" book. Readers and reviewers have simply to decide wether or not the physical chemistry of natural sedimentary particle systems set out in the book now adequately explain the geological features and phenomena illustrated.

Preparing the many progress reports, attending and organising seminars, conferences, field visits and preparing presentations, courses, lecture tours, etc. did involve study of thousands of textbooks and scientific papers over the years. However, the new knowledge introduced by this book clearly could not have been achieved without the advice and guidance of the outstanding academic scientists and the observations, competence and enthusiasm of Australia's most successful exploration team.

THE SCIENTIFIC METHOD

The new knowledge in this book has been achieved by the scientific method. Today scientists world-wide are dismayed by scientific reports and concepts that rely on surveys of opinion, exaggerated media reports, post-normal statistical assessments of likelihood, "it must be the way I think it is because I don't know of any alternative", "it is generally accepted that … therefore ….", etc. Intense competition for research grants has resulted in strong bias towards politically expedient investigations that are believed favoured by funding authorities. Once thriving geology departments have been downgraded to small divisions in Department of Geography, Department of Environmental Sciences, etc. Mineral exploration is difficult to finance and discovering new resources harder to achieve.

Since 1936 the 'scientific method' has been recognised by Australian law (Subsection 73B(1) of the Income Tax Assessment Act 1936) as:

> *Systematic investigative and experimental activities that involve testing a hypothesis (new idea) by deductive formulation of its consequences. These deductions must be rigorously tested by repeatable experimentation and logical conclusions drawn from the results of the experiments. The hypothesis must be based on principles of physical, chemical, mathematical, or biological sciences.*

This would include colloid science and current nanotechnology.

In 1970-74 Australian universities abandoned the procedure that had been used to that time for award of their highest degrees in science. DSc candidates were required to submit a doctoral thesis embodying an original research finding (details of a tested hypothesis). This was "peer reviewed" by two or more external scientists selected by the university as most appropriately qualified. It was recognised that a candidate who had tested an original hypothesis may be equally or better able to interpret the results than an external reviewer. Candidates were therefore entitled to a "right of reply" to the written report or comments of the universities' reviewers. In reply they could produce references or call on reviewers of their own selection. University authorities were able to fairly assess the candidate's new research finding and determine if it merited the award of their highest degree.

This procedure raised standards in all scientific disciplines to which it applied but by 1974 it was abandoned by all Australian universities as too tedious and time consuming to cope with the rapidly increasing number of candidates aspiring to higher degrees. With continuing rates of increase since 1970's, Australian universities now resemble production-line 'higher degree factories'! They quite rightly require higher degree candidates to meet very high standards but they are uniform standards requiring each candidate to conform to the limitations of the knowledge of his or her degree supervisor. Significant new discoveries cannot conform to what is currently "generally accepted".

All publicly funded research in Australia tends to digress, at least to some extent, from the scientific method toward the extreme case depicted in the American cartoon below (Figure 1). Competitive research proposals are written to get research grants rather than to advance our knowledge by resolution of long-standing problems. Researchers spend more time looking at computer screens than looking at rocks and mineral deposits!

THE CENTRAL HYPOTHESIS

Most people recognise that sediments are formed from tiny sediment particles and chemical precipitates and it is quite logical that sediments in the ancient oceans had the same physical, chemical and fluid properties as sediment accumulations in the oceans today. We are therefore able to assume that these ancient particle systems that have now consolidated to rocks containing mineral deposits, may have contained or been comprised of colloidal sediment particles like clays, colloidal silica and hydrous ferromagnesian particles. The total surface area of the billions of particles in every cubic meter of mud is about 60,000,000 square meters.

Therefore the central hypothesis that has been systematically tested is: -

If ancient sediments were particle systems containing or comprised of colloids, evidence of the former colloidal properties of these materials should be preserved in the rocks. We should be able to find evidence of former plasticity, diffusion, cohesion and fracture, mobilisation by shaking or movement (called thixotropy) caused by earthquake shocks or sliding and flow downslope, and sudden resetting where mudflows or intrusions were about to stop (called rheopexy). The

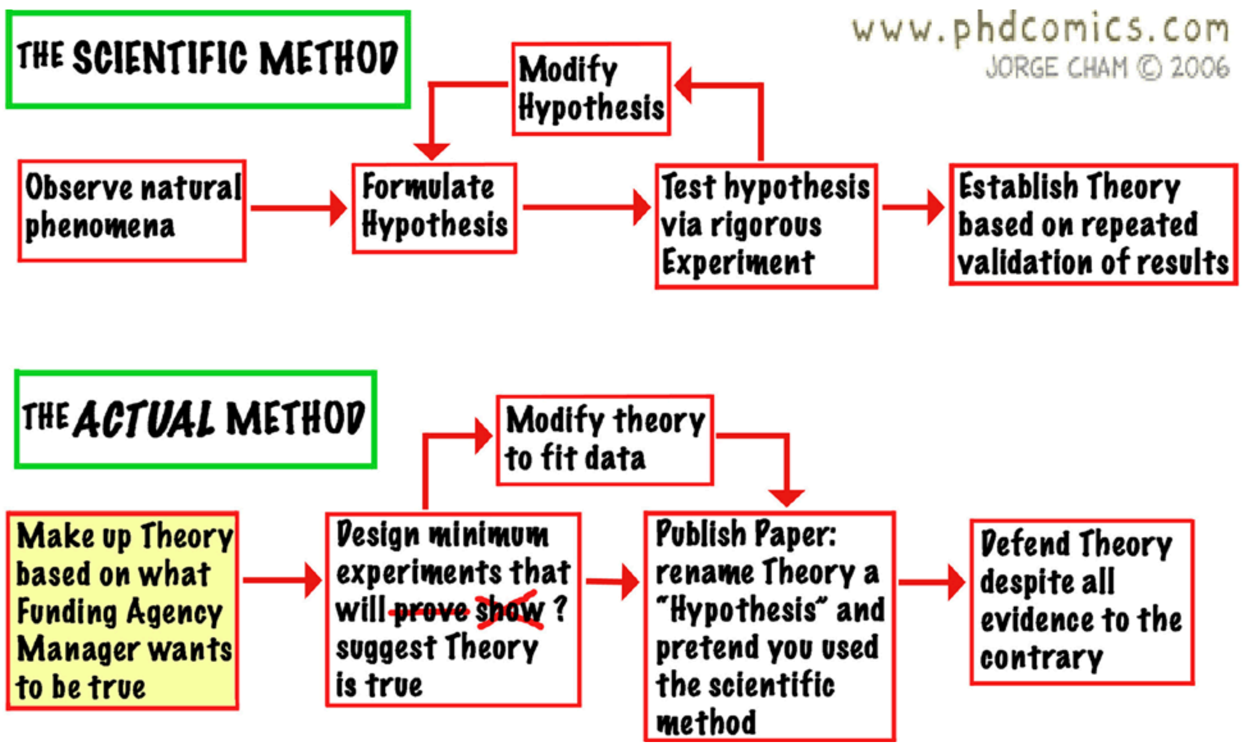


Figure 1. This cartoon by Jorge Cham, 2006, depicts the unfortunate trend from the scientific method to expediency in obtaining research grants.

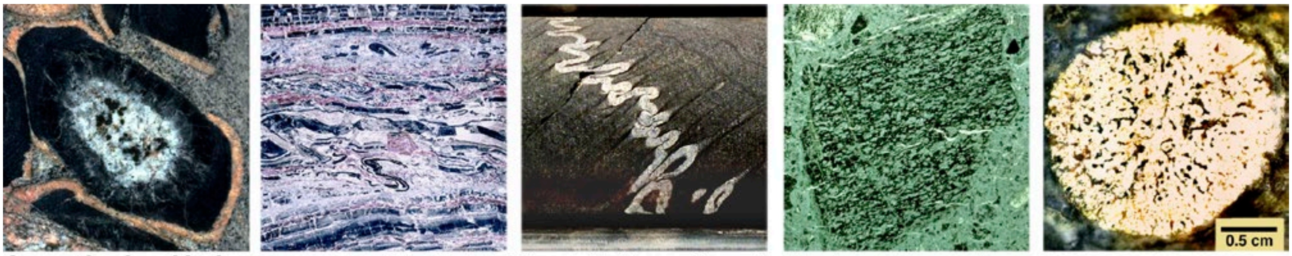


Figure 2. Five examples of the evidence that ancient sediments and mineral deposits contained or were comprised of colloidal particles.

rocks and mineral deposits should contain residual hydrous minerals and show aggregation or 'clotting' of the fine-grained components (called accretion). We should see spontaneous shrinkage cracks (called syneresis cracks) in aggregates and nodules, overgrowth and rimming structures (called concretion), bulbous 'loopy' vein intrusions (called ptygmatic), ordering patterns and enhanced crystal growth.

This hypothesis has been rigorously tested by repeated experimentation. The abundant evidence of the former colloidal properties of ordinary rocks and mineral deposits can be seen and recorded photographically or as observational data. The simple experiment can be repeated by anyone willing to look at the rocks and consider the observations from first principles including those now established in current colloid science.

Ordinary rocks and mineral deposits do contain this evidence in abundance (Figure 2).

Every picture in *"The Origin of Rocks and Mineral Deposits"* book or similar ones that can be recorded by others is a valid experimental test of the central hypothesis.

The whole research program is definitely interdisciplinary. It is dependent on current colloid and surface chemistry as much as on geological observations. The research began with one of the most puzzling observations relating to the porphyroids. In 1958 some geologists considered these to be "volcanics" and possibly the source of the ironstone and associated copper and gold ores that were being mined at Tennant Creek in central Australia.

THE INITIAL IDENTIFICATION OF ACCRETIONS

Government geologist, J. F. Ivanac, studied the geology and mineral deposits at Tennant Creek, Central Australia in 1954. He reported a most unusual variety of porphyroid associated with a gold prospect called Black Angel that was one of the largest ironstone masses known on the field at that time. Detailed mapping showed the unusual porphyroid to be intrusive and formerly mobile (Figure 3). The government geologists did not know what it was and they called it the "pigeons egg conglomerate".

These irregular intrusive porphyroid lenses at the Black Angel Prospect in Tennant Creek contained large ovoidal chert nodules (Figure 4). Their internal concentric banding is similar to that found in much larger geodes but many of the ovoids were fragmented and randomly oriented pieces in the matrix showed the banding truncated at the margin of the angular fragments (Figure 5). The concentric banding appeared primary and not due to later weathering. The occurrence of chert ovoids instead of the usual ovoidal embayed quartz "phenocrysts" in most other porphyroids from the outcrops and drill cores at Tennant Creek was initially quite puzzling.

Chert was thought to be a hardened form of colloidal silica so advice on the possible origin of these ovoids was sought from a senior colloid chemist. Specimens of the Black Angel "pigeons egg conglomerate" together with a selection of so-called quartz "phenocrysts" from more typical Tennant Creek porphyroids and sheared porphyroids as illustrated in Figure 6 were taken to Professor A. E. Alexander of University of Sydney.

In 1958 Professor Alexander, author of Alexander and Johnson *"Colloid Science"*[7] was certainly the best colloid scientist in Australia and a world leader in this specialised branch of surface chemistry and particle interactions.

After examination of the specimens and particularly the concentrically banded chert ovoids in the Black Angel porphyroid he was completely confident of their origin. *"Mr Elliston, those are not concretions, they are accretions!"* Professor Alexander explained that quartz was not soluble in water including normal ground water and stream water in the cycle of erosion. It is transport-

WHAT ARE THE BLACK ANGEL PORPHYROID OVOIDS?

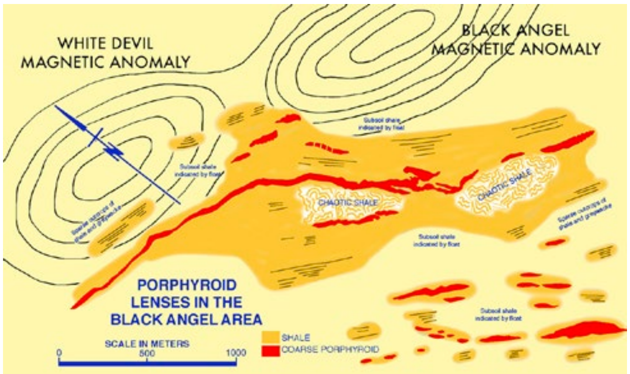


Figure 3. Map of the mysterious porphyroid lenses and magnetic anomalies at the Black Angel prospect, Tennant Creek.

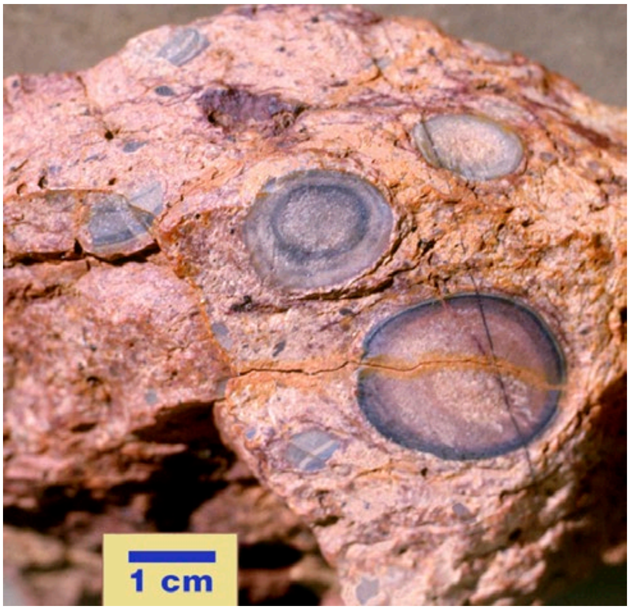


Figure 4. Chert ovoids in the Black Angel porphyroid have concentric internal diffusion (Leisegang) banding.

Figure 5. Banding in Black Angel porphyroid chert ovoids was formed before some were broken in subsequent liquefaction of the matrix. The bands were not formed by exposure and weathering.

ed as gravel and sand grains and generated as sea sand. Quartz does not dissolve in seawater by dispersion of anions and cations as a solution but it does hydrolyse (react with water) in slightly alkaline seawater (pH 7.9 to 8.3). This process was later found to be "proton promoted dissolution"[8] as shown diagrammatically in Figure 7.

Professor Alexander explained that to form accretions in ordinary marine sediments such as the turbidite deposits at Tennant Creek the interstitial polymeric silica particles aggregate into large globules of silica gel if the mud at a certain stage of consolidation is reliquefied and able to flow.

He pointed out that there is a critical concentration (distance between charged particles) at which "close packing" sets in and that this applies to all the charged particles or colloidal components of natural sediments. He was therefore confident that quartz ovoids from other porphyroid lenses in Tennant Creek that showed evidence of former shrinkage (syneresis), of having been soft or plastic or aggregates of smaller accretionary clusters were also accretions. This applied to all the colloidal components in the original sediment including the clays and hydrous ferromagnesian minerals that are the other major components of normal sediments.

There was obvious certainty about the Black Angel chert ovoid "porphyry" and clear evidence of its extension to other porphyroids in Tennant Creek that had been considered to be of volcanic or igneous origin. It was initially unclear how far the principles of particle aggregation (DLVO theory) [9,10,11] applied but a new and exciting new avenue of investigation was opened up. It was particularly relevant to the source of the ore deposits associated with the porphyroids. If the porphyroid

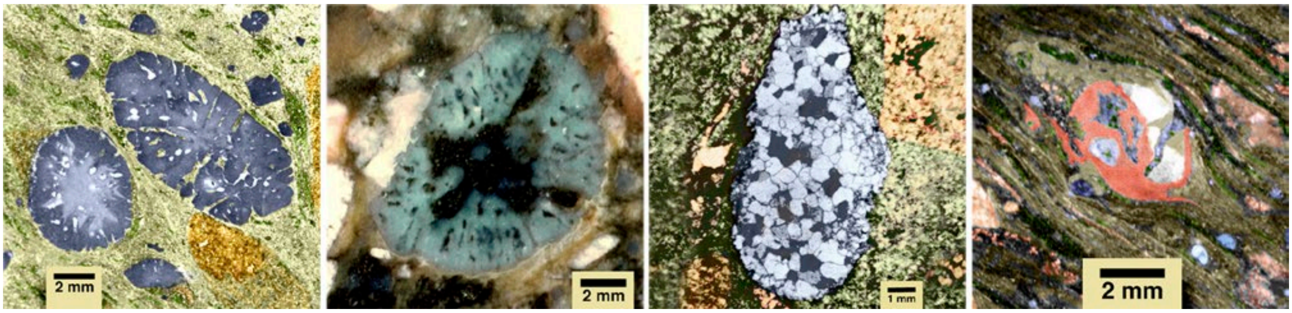


Figure 6. Quartz "phenocrysts" from the Tennant Creek porphyroids are typically rounded, embayed with crack patterns interpreted as due to syneresis shrinkage. Some show soft or fluidal contacts with feldspar, many are mosaics of smaller interlocking crystals and there are clear examples of colloidal silica (jasper, chert) aggregation.

"phenocrysts" had crystallised from accretions, syneretic desorption of critical clusters of insoluble sulphide and oxide ore and gangue minerals during their condensation was clearly the source of the ore.

THE SURPRISING VEHEMENCE OF OPPOSING VIEWS ON SIGNIFICANT DISCOVERY

The discovery that porphyroidal textures result from crystallisation of accretions in all sorts of sediments (including limestone) mobilised during diagenesis (the process of change between sediment and rock) is revolutionary. As the research was developed further, hundreds of textbooks and papers studied and specialist academic advice obtained, it became clear that a large majority of "middle ranking" academics remain stubbornly committed to historic concepts, existing old interpretations and ideas developed before the advent of current surface chemistry and nanotechnology. There is real apprehension about change.

More thoughtful individuals, especially senior academics working to advance the frontiers of knowledge themselves, are prepared to consider the detailed observations and draw logical conclusions directly from the observational data. Professor S. W. Carey from the University of Tasmania came to Tennant Creek and after careful examination of the evidence, he fully accepted and became keenly enthusiastic about the new discoveries. He organised an international symposium in 1963 at the University with field visits to Tennant Creek to introduce the new concepts more widely.

Evidence such as the Black Angel porphyroid with chert ovoids should be conclusive. It was later shown that large concentrically banded geodes that lapidarists cut and polish for sale as ornaments also have an accretionary origin. The aggregation of smaller nodules of silica gel (now chert) and the Leisegang banding, central crystal cavity and fluid extrusion channels are shown in the cut section in Figure 8.

This and evidence for the accretionary origin of Tennant Creek porphyroids was accepted by some geologists working on the field, colloid chemists and a number of perceptive academic geologists. In addition to Professor S. W. Carey, Professor T. F. W. Barth from Oslo, Professors J. C. Jaeger and Anton Hales from Australian National University, Professor Beryl Nashar from Newcastle, Professor R. L. Stanton from University of New England, Professor T. W. Healy from PFPC at University of Melbourne and Assoc. Professors K. L. Williams and R. J. Hunter from University of Sydney have accepted and found the evidence for accretion and con-

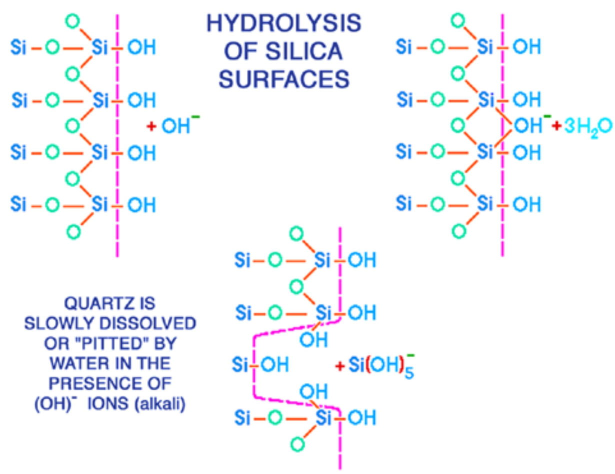


Figure 7. The molecular dispersion from crystalline silica in water as $Si(OH)_4$ is catalysed by hydroxyl ions of an alkali or base. Seawater is slightly alkaline and therefore silica (and most silicate surfaces) "disperse" by these surface reactions. In sea water and within marine sediments the small neutral $Si(OH)_4$ molecules polymerise to short chain polymeric silicic acids called "oligomers". (From Iler, 1979, fig. 1.11.)[8]

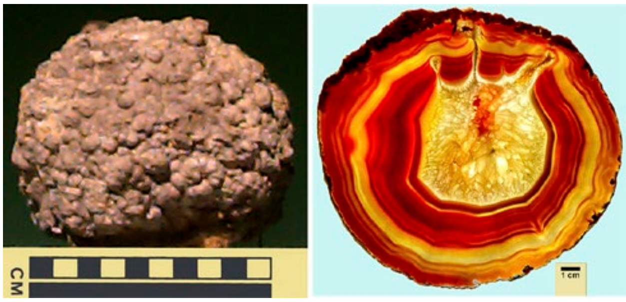


Figure 8. Following Professor Alexander's recognition that the concentrically banded chert ovoids in the Black Angel porphyroid were accretions, it was later found that much larger internally banded geodes are also aggregates of smaller polymeric silica nodules. Concentric (Leisegang) banding is due to different diffusion rates for ions and desorbed electrolytes that control precipitation of impurities [$Fe(OH)_3$].

cretion in rocks historically classified as "volcanics" and "igneous" to be clear and compelling.

In the long course of the systematic investigation many more earth scientists have assisted in assembling the great body of observational data (4,600 photographs of evidence of former colloidal processes preserved in the rocks) and recognised that the principles apply to all rocks and mineral deposits derived from natural sediments. Forty-eight senior scientists are listed in the book but since printing and distributing the Australian preview edition there are now many more.

Concretionary structures can only be formed by precipitation of charged particles diffusing to form concentric layers round nuclei that desorb ions and charged particles (synerectic). They are unique non-random structures that can only be formed in aqueous particle systems. They are conclusive evidence that the rocks in which they occur were lithified, crystallised or simply hardened by chemical dehydration reactions from aqueous particle systems. Concretions or orbicules have been found in siliceous shales at Tennant Creek, in porphyroids at Whip Spur, South Queenstown, Tasmania, and the variety of large concretions called orbicules are found in many granites worldwide. Orbicules have also been found in most other varieties of so-called igneous rocks, sediments, and "volcanics" except actual volcanic ejecta, ash and basalt.

Because concretions are such clear and compelling evidence of the former particulate and diffusive nature of the crystalline or lithified rocks in which they occur, during the course of the long investigation to establish the origin of rocks and mineral deposits using current physical chemistry of small particle systems, orbicules or concretions have been photographed or recorded in granite, diorite, rhyolites, norite, aplite, gabbro, dolerite, pyroxenite, peridotite, serpentine, chromite, kimberlite, dolomite, limestone, siliceous shale, carbonatite, latite, amphibolite schist, jasper, chert, quartz veins, and siliceous magnetite lodes.

All these examples are characterised by 23 features resulting from the particle system properties that give rise to them. The rounding, concentric rimming and former soft plastic and fractural condition are most obvious but most examples show only about seven or eight of the 23 characteristic features.

The physical and chemical processes by which orbicules and concretions generally are formed are set out in complete detail in the book *"The Origin of Rocks and Mineral Deposits – using current physical chemistry of small particle systems"*.

A few examples concretions including those called orbicules are illustrated in Figure 9.

INCREDIBLY OBDURATE RESISTANCE

The revolutionary new hypothesis that ancient sediments were particle systems with the same rheological (ability to reliquefy) and physico-chemical properties as those now established for sediments accumulations of today remains a horrendous anathema to many academic geologists, editors and PhD graduates. They have abandoned the correct scientific method by which we should draw logical conclusions directly from factual observational data and measurements. The popular or majority view is considered more important and only papers and textbooks that conform to existing ideas and traditional interpretations are approved for publication in scientific journals.

Geology and other scientific disciplines to the extent that the correct scientific method is no longer used, are "stuck in a rut".

AusIndustry and Australia's most distinguished leaders in colloid science have ensured that our whole program is based on repeatable experimentation and that conclusions are based on sound principles of the physical chemistry of small particle systems and nanotechnology. However, the results of prolonged experimentation are still not "current knowledge" that is available in the public arena on a reasonably accessible worldwide basis.

The most significant new contribution to science from this research is that disturbance of wet sediment pastes allows colloidal particles in natural sediments to rearrange themselves into denser clusters called accretions so that surface energy is reduced. The large accretions that

Figure 9. Examples of concretions include those called orbicules and oolites.

are formed during flow subsequently liberate colloidal ore metal sulphide suspensions into brines as they spontaneously divest surface adsorbed water (called syneresis). Rock masses are heated by chemical dehydration reactions as the pre-ordered particle aggregates finally crystallise.

It is clear that mineral deposits are not deposited from solution but from colloidal dispersions formed by successive synerectic desorption of critical clusters. Granitic, porphyroid and metamorphic minerals crystallise from precursor hydrosilicate accretions. These are formed by shear or viscous flow of mobilised semi-consolidated sediments. Syneresis of the accretions formed in large volumes of sediment mobilized during diagenesis desorbs ore and gangue minerals. Quartz veins, pegmatites, aplites, ferromagnesian mineral-rich rocks and massive intrusive iron ore accumulations are formed by rheological separation.

The vast majority of geologists still know very little or nothing about the way that the charged particles in natural sediments interact with each other and with the charged ions in fluids surrounding them. The main components of natural sediments are clays, polymeric silica particles and hydrous ferromagnesian minerals that carry a surface charge. The surface charges on natural sediment particles interact with those on adjoining particles, with polar water molecules and with the ions of any electrolytes dissolved in the pore fluids.

Many years of study and advice from world leaders in geology and in colloid and surface chemistry have determined the physicochemical processes by which many previously unknown geological textures and structures were actually formed. These include iron ore oolites, ptygmatic folding, granite orbicules, rapakivi textures, myrmekites, accretions, concretionary structures in mineral lodes, discordant folding and plastic deformation of minerals, etc. Several examples are illustrated in Figure 10.

The origin of these structures, of migmatites, porphyroids, granitic rocks and mineral deposits is still not current knowledge, information or experience. The scope of the core research and application of this book is extraordinarily wide. The principles of current surface chemistry apply to all rocks and mineral deposits that have been derived from natural sediments.

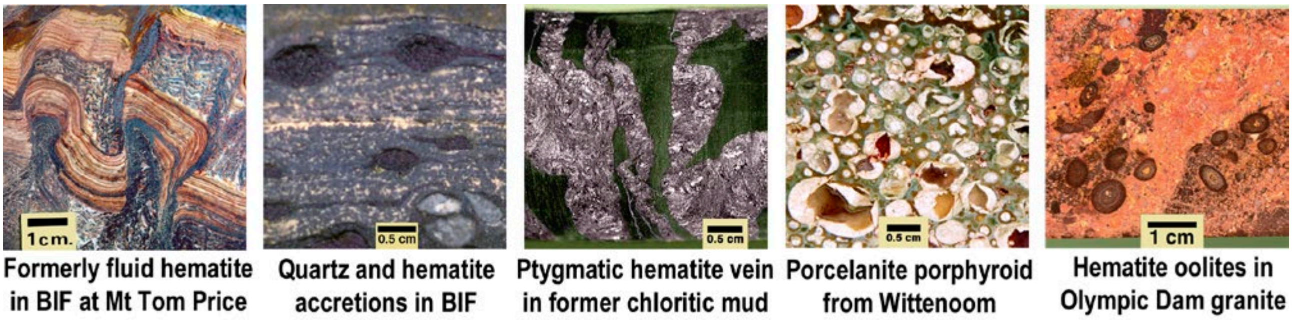


Figure 10. Former mobility of iron ore, accretions, ptygmatic folding, and concretions are now explained.

Those trained only in conventional geological principles must recognise the nature of any significant advance. It is new, unfamiliar, not yet accepted, and it must differ from traditional beliefs. Existing personal beliefs and traditional assumptions constitute the main impediment to the advance of science. The objective of this book is to present the primary data, the observations representing the experimental results and the details of the colloid and surface chemistry and rheology (fluid properties of clay, mud and gelatinous precipitates) that now explain the observations.

EXPLORATION SUCCESS RECORD

It has been demonstrated that an understanding of these processes can be used to achieve higher success rates and greater cost-effectiveness in mineral exploration.

For the first 26 years after Professor Alexander's advice that the chert ovoids in the Black Angel porphyroids were accretions, the research was developed in conjunction with an active mineral exploration programme in order to improve its effectiveness and success rate. It succeeded. This story of the successful application of the developing research is recorded in the book *"Australians Successfully Exploring Australia – and developing the science and technology to do it"*.

As soon as the origin of the mineral deposits at Tennant Creek was understood five new mines were discovered in different locations on that field with the first fifteen exploration holes drilled. In the period 1967 to 1984 before another company funded the ongoing research, a further mine was discovered on the Tenant Creek field, a new coalmine and three other significant mineral deposits developed elsewhere in Australia. A total of nine new metalliferous mines and 33 associated minable ore bodies established a record for the most successful mineral exploration group in Australia.

This has been confirmed by independent comparative studies commissioned by competitors. CRA Exploration Ltd commissioned McKinsey & Company Ltd, Management Consultants from New York in 1975 and Western Mining Corporation with a study of the *"Economics of the Australian Mining Industry"* led by Professor Brian Mackenzie in 1984. The record for exploration success using the new understanding of how rocks and mineral deposits were formed remains unsurpassed.

The long-running systematic investigation of the origin of rocks and mineral deposits including costs of highly qualified academic consultants, establishment of libraries, continuing access to world scientific literature, etc. was financed by the success in developing new resources.

PROGRESS REPORTS

In both the period of funding by Peko-Wallsend 1957 to 1984 and by CRA Exploration – Rio Tinto 1984 to 1996, hundreds of company reports relating to specific prospects and exploration or acquisition projects were prepared. In addition to these, scientific papers and presentations that record the progress of the new research could be summarised as: -

Papers published:	14
Public lectures, presentations and courses:	27
Company Research Progress Reports for Peko-Wallsend Limited:	19
Company Research Progress Reports for CRA Exploration – Rio Tinto;	66
Books:	3

The companies were keen to have the new scientific discoveries understood and applied to improve success rates and cost-effectiveness in developing new resources. Geopeko Limited, the exploration subsidiary of Peko-Wallsend Limited demonstrated this success.

From an initial misunderstanding that it would be easy for the much larger CRA Exploration team to be "brought up to speed" the progress reports for that company became increasingly detailed and authoritative.

Progress reports include contributions to the symposia held at the University of Tasmania in 1963 and its review in 2007, 14 consultant reports to the companies by Professor T. W. Healy on physico-chemical processes in the diagenesis of sediments and many of the later reports to CRA Exploration geologists. These are essentially substantive treatises based on numerous field observations that support their conclusions. AusIndustry has monitored all research for compliance with the prescribed scientific method since 1984.

Those prepared for CRA Exploration were released for publication on 27th September 1995. Each of these progress reports advances our knowledge of its topic by using current physical chemistry of small particle systems where this is relevant to the interpretation of the observations recorded. Figure 11 is a photograph of the progress reports relating to the long-running industrial research projects. The yellow introductory booklet contains the e-book on CD that was prepared for evaluation.

They are fundamental scientific papers explaining well-known problematic geological observations by using a wider range (interdisciplinary) of established physico-chemical processes.

Figure 11. Progress reports relating to the long-running industrial research projects include the yellow introductory booklet containing an e-book on CD. This was prepared for evaluation with direct links from the text to figures, glossary and references.

Some of the more significant titles of these early 1990's conclusive studies are illustrated in Figure 12.

THE COMPLACENCY OF CONSENSUS AND CONSTRAINTS OF CONVENTION

Science is the intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experiment. This has largely been abandoned in modern times.

To be accepted into a University one has to provide the 'right' answers in exam papers. The 'right' answers are those considered to be in accord with present beliefs and rigorously maintained existing university standards. Students are brainwashed in University courses so that 'scientific correctness' prevails in geology.

To be successful in academic research one has to publish papers that present the 'right' answers to questions that are in accord with current beliefs and 'acceptable' theories. However logical, new conclusions from direct observation tend to be disregarded.

Academic training is constrained to orthodoxy and established lines of enquiry by its objectives in achieving highest technical standards, academic status, equivalence and uniformity in graduate levels, but above all by acceptance and recognition of its research, teaching, and graduates. The endeavour is for academic recognition and status rather than acquisition of new knowledge.

The academically oriented thinker is extraordinarily difficult to "teach", even by observations in the rocks themselves where they are clearly inconsistent with theory. This is because he or she attaches such great importance to "right" premises and pre-suppositions. Divergent views or "heresy" become for those in pursuit of an academic career a threat of excommunication or non-acceptance by peers.

Years ago Lowell wrote:

> *Is anything of God's contriving endangered by enquiry? Was it the System of the Universe or the monks that trembled at the telescope of Galileo? Did the circulation of the firmament stop in terror because Newton laid his daring finger on its pulse?*

When Professor S. W. Carey was first shown the evidence for aggregation of particles in remobilised dense mud and the way these close-packed clusters subsequently crystallised to textures that had previously been interpreted as "volcanic" or "igneous", he recognised the fundamental nature of this significant scientific discovery. In his 1963 symposium on gravity sliding of uncon-

Figure 12. Some of the more significant progress reports detail the features of ore source rocks, the aqueous chemistry of silica, the formation of siliceous accretions, the origin of non- alluvial oxide ores, the geology of the iron ore provinces, the formation and crystallisation of clay accretions, the formation of framboids and the origin of metal sulphide species that accumulate as mineable ores.

solidated sediments towards the deeper parts of the sedimentary basins he wrote:

> *These proposals frankly shocked me, because once these new premises and processes are granted I cannot see any discontinuity short of profound revision of many of our cherished concepts on ores and a wide group of "igneous" rocks."*

The evidence presented at the symposium convinced most of the geologists attending. However, most were left wondering how far the new principles applied and three or four attendees revealed their strong emotional commitment to existing interpretations and traditional assumptions made before the properties and surface chemistry of charged particles were known. It emphasised the reality of Professor Carey's edict. For many otherwise competent scientists: - *"We are blinded by what we think we know."*

However, the outcome was years of study of examples and accurate recording of observational data. The central hypothesis is established as correct but appropriately fair and competent refereeing remains extraordinarily difficult for academic geologists committed to historic assumptions and existing university teaching and "cultures".

Initial studies of mine openings and drill cores at Peko Mine found the quartz-magnetite lode contained oolites (fish-egg sized concretions) as illustrated in Figure 13. To understand the ore forming processes it was clearly necessary to understand how these concretions could form and then crystallise to quartz-magnetite.

This was achieved and first published in *"The genesis of some epigenetic type ore deposits"*, 23rd Session of Int. Geol. Congress, Prague, August 1968. Published in Organ. Czech. Soc. of Min. and Geol., 14(2): 129–139. The study of concretions extended to orbicular structures in granites was published as *"Orbicules: an indication of the crystallisation of hydrosilicates",* 1., Earth-Science Reviews, 20: 265–344 in 1984.

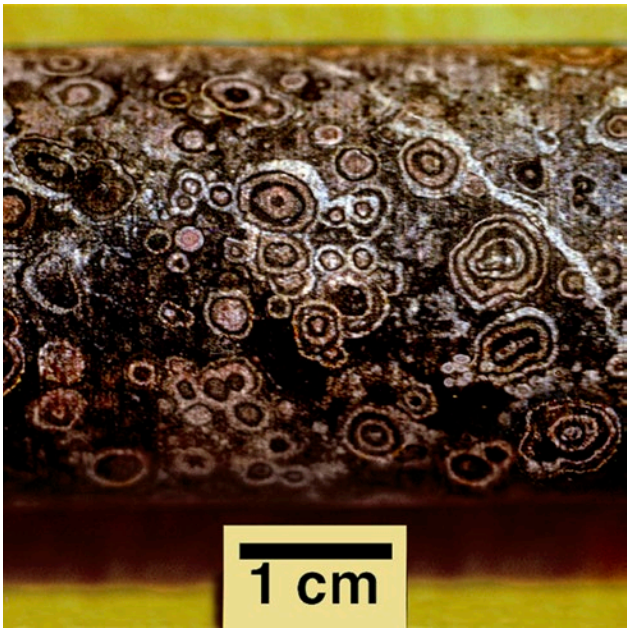


Figure 13. Fish-egg sized concretions or oolites were found in the quartz-magnetite lode at Peko Mine, Tennant Creek.

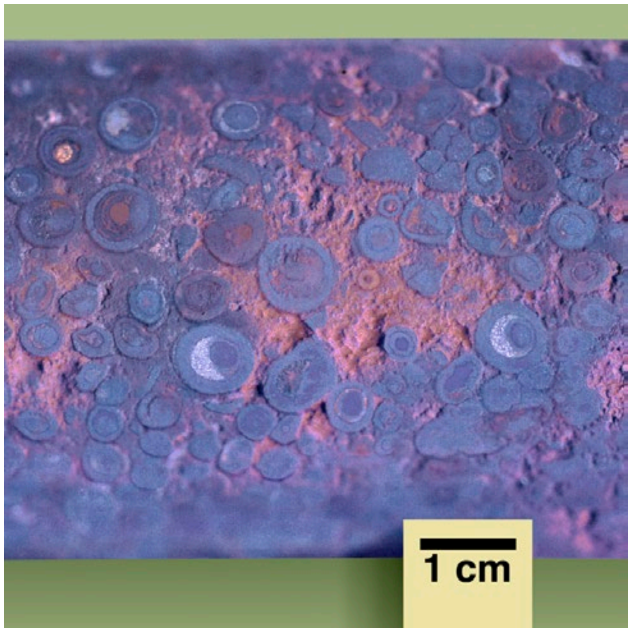


Figure 14. Oolitic hematite oolites in the hematite lode at the Olympic Dam Mine in northern South Australia show that the minerals in this very large lode also crystallised from colloidal ferric-hydroxide precursors.

Years later a visit to the Olympic Dam Mine in South Australia on 8th July 2002 revealed that the mine geologists at that mine had also discovered hematite oolites in the large intrusive hematite breccia body that contains the mineable ore. The hematite oolites are exposed in the mine openings and drill cores. Excellent specimens are exhibited as curios in the mine geological office display cabinet. However, the Chief Mine Geologist and most of the academic geologists on this Geological Society visit were disinterested and did not recognise the significance of the occurrence of hematite oolites as an indication of the origin of the ore. Visitors to the core yard in 2002 were invited to photograph the core illustrated in Figure 14.

The advancement of science is totally dependent on logical conclusions from measurement and observation. Research proposals and attainment of higher degrees are focused on what is acceptable to the existing mainstream of professional geoscience practice and this has become the criteria for publication used by editors of scientific journals.

HISTORY OF "PEER REVIEWING" FOR INTERDISCIPLINARY RESEARCH

When the interdisciplinary nature of this industrial research and the long-running systematic investigations that were the basis of many progress reports are understood, reviews of *"The Origin of Rocks and Mineral Deposits – using current physical chemistry of small particle systems"* have been very successful.

However, not all potential publishers have been able to appreciate the interdisciplinary nature of the research on which the new knowledge of the origin of rocks and mineral deposits is based. Thorough scrutiny and competent review of this book was achieved largely as a reaction to breach of an agreement to referee the manuscript properly. That potential publisher was established to promote and advance the science and publish or assist in the publication of scientific knowledge relevant to Australian industry. The manuscript was rejected because at that stage it was yet to be accepted into the mainstream of professional geoscience practice.

How could new innovative industrial research, held confidential for twelve years because its application had demonstrated a 320% increase in exploration cost-effectiveness, have become accepted into the mainstream of professional geoscience practice if it were not published?

Experience has shown that many otherwise competent senior geologists know nothing about synerectic desorption or the formation of critical clusters. Similarly many proficient chemists are unaware that occurrences of granite contain orbicules or incongruous minerals like calcite and hematite. Review by teamwork involving both geologists and chemists or by scientists adequately skilled in both disciplines is essential. Reviewers have to determine whether or not the physical and chemical processes set out in the book provide adequate explanations for the numerous geological observations.

The book contains new knowledge (details of the physico-chemical processes by which rocks and mineral deposits are formed) that is important.

The decision to dishonour the agreed refereeing procedure led to further questioning of the research method and validity of the significant results. AusIndustry (now the Department of Industry, Innovation and Science) wrote on 28th November 2005 commending the results to date but wanted to ensure that these and ongoing research used the scientific method as required to qualify for tax incentive subsidies.

AusIndustry were extraordinarily thorough. They sent a representative to view the progress reports, image library of 4,500 catalogued photographs recording the geological observations, the reports of the colloid chemists providing the physico-chemical processes in diagenesis, the technical library and the stacks of hundreds of photocopies of relevant geological and colloid science papers that had been studied in the course of the work.

More senior officers in the Department challenged the initial enthusiasm of the AusIndustry representatives. Eventually Dr Tom Honeyman was asked to investigate and report directly to the Industrial Research and Development Board. Some three months of questioning and discussion by correspondence, e-mail and telephone provided detailed information. Dr Honeyman recognised that illustrations in the reports and every observation recorded in the image library is a valid experimental test of the central hypothesis. He reported positively to the Industrial Research and Development Board at the end of July 2006. At first the Board was unable to accept that using current physical chemistry of small particle systems had discovered the origin of rocks and mineral deposits. A sub-committee of the Board was selected to further examine Dr Honeyman's report and the detailed information on which it was based. The IR&D Board approved the project and confirmed use of the scientific method on 7th September 2006.

AusIndustry issued a certificate stating that the correct scientific method had been used for this project on 8th September 2006. Ian Bell, AusIndustry Assistant Product manager, gave formal approval to use the AusIndustry "proudly supported by" logo on the *"Origin of Rocks and Mineral Deposits"* and the verification reports on 6th October 2006. This was for an Australian preview edition and any subsequent international hardcopy versions. After thorough review, AusIndustry had recognised the scientific validity and significant industrial value of the research.

There was a very positive reaction to the earlier breach of the agreement to referee the research properly and AusIndustry's competent evaluation. Reviewers whose reports had been disdainfully ignored, principally Professor Ross Large, Director of the Centre of Excellence in Ore Deposits (CODES) at the University of Tasmania and Mr Kim Wright, Manager, Earth Resources Foundation, University of Sydney, organised a symposium to review the whole research program and exploration techniques that had achieved its outstandingly successful application. The Australian preview edition of the *"Origin of Rock and Mineral Deposits – using current physical chemistry of small particle systems"* was printed for this symposium held on 22-23rd November 2007. Fifty-one senior scientists contributed presentations papers and discussion that has resulted in one of the most thoroughly scrutinised and competently reviewed scientific treatises in history.

THE CODES SYMPOSIUM AT THE UNIVERSITY OF TASMANIA 22ND TO 23RD NOVEMBER 2007

This Symposium was held to review the advance in understanding the origin of rocks and mineral deposits that had been achieved since Professor S. W. Carey convened the first international symposium in May 1963. Professor Ross Large, Director of CODES at the time, gave the introductory presentation. His first slide is illustrated as Figure 15.

Professor S.W. Carey, Convenor, introduced and defined the meaning of the term "syntaphral" at the 1963 symposium. For general understanding it would

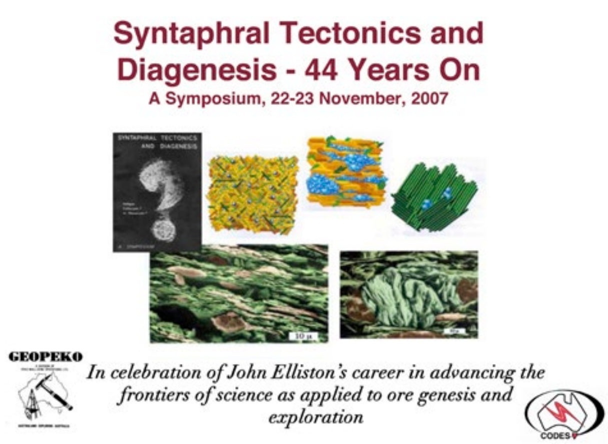


Figure 15. The introductory slide for the CODES Symposium at the University of Tasmania in November 2007.

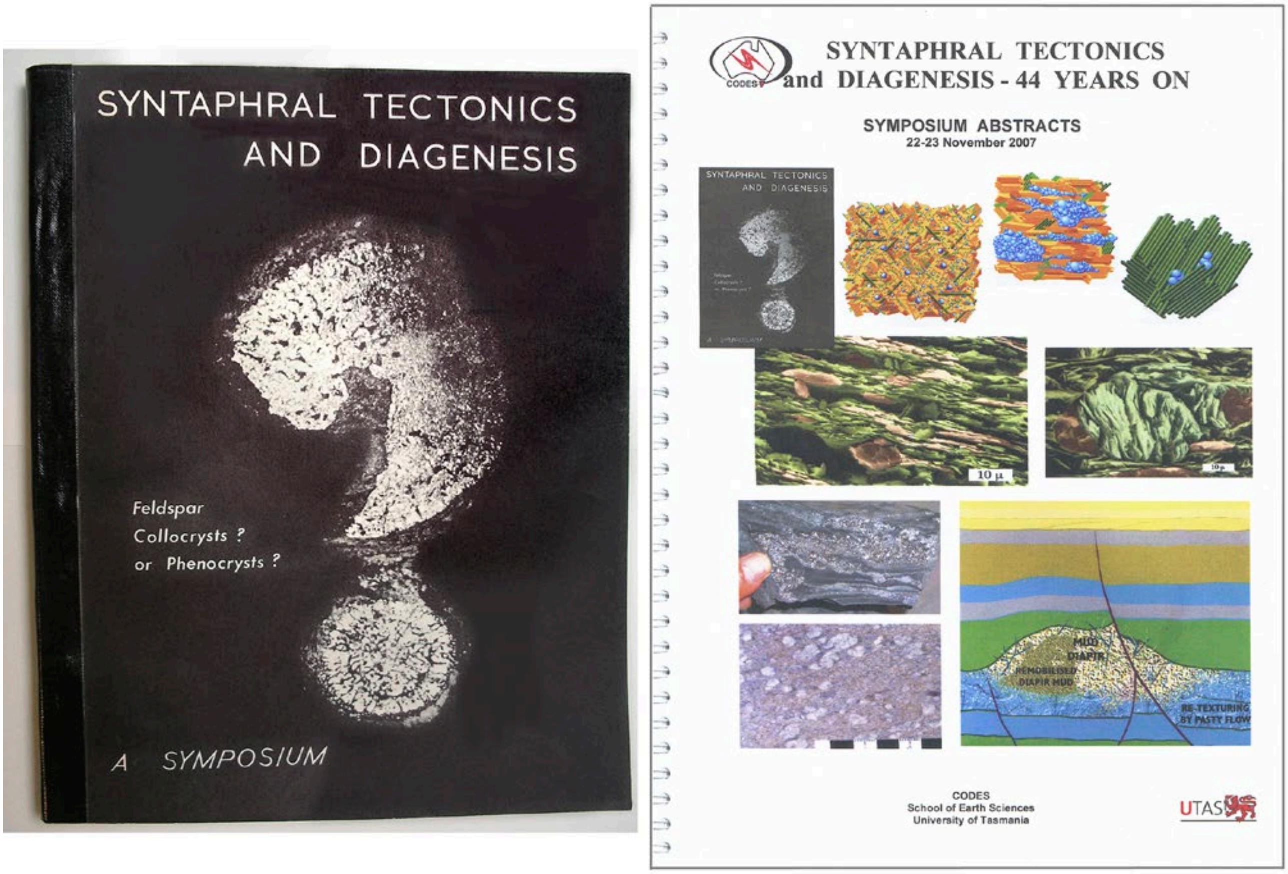


Figure 16. Records of the Symposia held at the University of Tasmania to introduce and evaluate the interdisciplinary research programs.

have been much simpler to describe the topic of this symposium as "Structures and re-texturing of fine-grained sediments by mudflows and sliding on submarine slopes". Many geologists are not aware that "syntaphral" means "towards the trough" or "downslope".

Professor Ross Large, Professor R. L. Stanton, Rob Ryan, Bob Richardson, John Elliston, Professor T. W. Healy, Kim Wright, Dima Kamenetsky, Jacob Rebek, Brian Williams, John Davidson, and Dr Ian Gould presented key papers at the 2007 symposium. Records of the 1963 symposium introducing the new concepts and the 2007 symposium evaluating and celebrating its completion are illustrated in Figure 16. Professor Ross Large introducing John Elliston's contribution is illustrated in Figure 17.

The Australian preview edition of *"The Origin of Rocks and Mineral Deposits - using current physical chemistry of small particle systems"* was printed as an e-book and distributed for participants to review the progress of the research since 1963 at this symposium.

Figure 18 is two pictures from Professor T. W. Healy's presentation at CODES Symposium, November

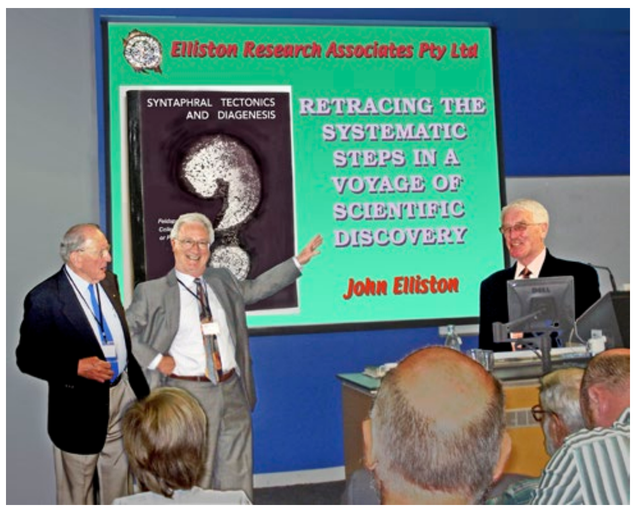


Figure 17. John Elliston (left), Professor Ross Large, Director of CODES, and Professor T. W. Healy, Particulate Fluids Processing Centre, University of Melbourne (right), at the symposium on sediment mobility and ore genesis at CODES in Hobart, November 2007.

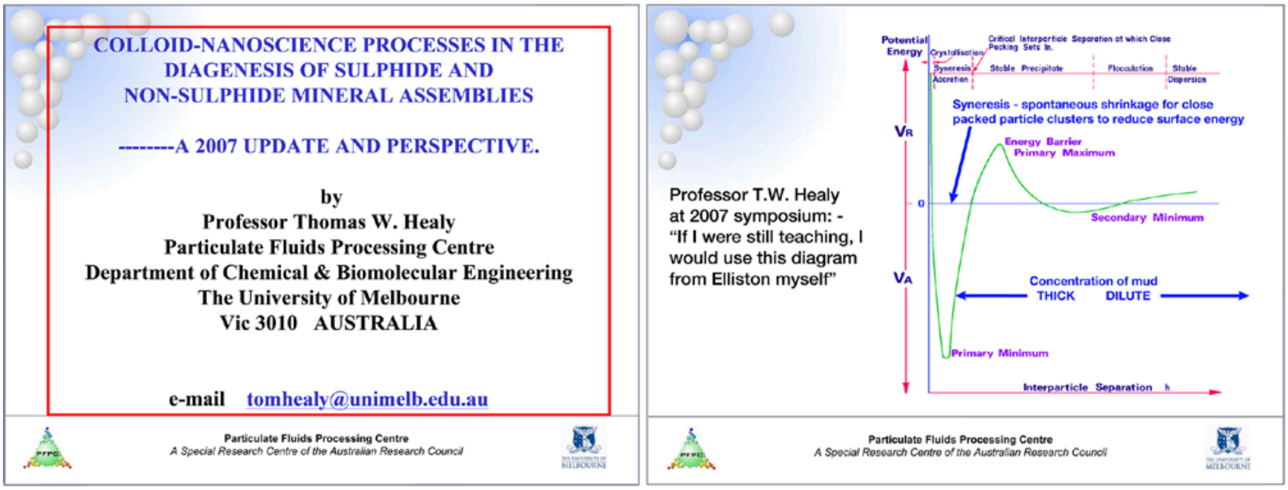


Figure. 18. Pictures from Professor T. W. Healy's presentation at CODES Symposium, University of Tasmania, November 2007.

2007. He explained DLVO theory[9,10,11] and his research that had measured the interparticle forces in relation to distance between particles (concentration of colloidal suspension or paste) that had confirmed it.

Professor T.W. Healy, AO, FRACI, FAA, FTSE, is one of the most highly qualified colloid and surface chemists in the world. His research group adapted an atomic force microscope to measure the interparticle forces in relation to particle separation (concentration) in 1998 as shown in Figure 18. Many geologists remain unaware that DLVO theory[9,10,11] is now confirmed as a natural property of colloidal particle systems such as liquefied mud. In thick mudflows or intrusions therefore plate-shaped clay particles, rod-shaped ferromagnesian hydrates and spherical polymeric silica globules form close-packed clusters that crystallise by exothermic dehydration reactions to result in porphyroid, metamorphic and granitoid textures.

Many examples of clear evidence for gelatinous precursors, polymeric silica and the formation of accretions and concretions were presented and discussed. A selection of these is illustrated in Figures 19 to 23.

Figure 24 is a group photograph of thirty-eight of the fifty-one participants at the CODES Symposium. It includes a number of the senior scientists who have made significant contributions to the Geopeko/CRA/Elliston Research Associates research.

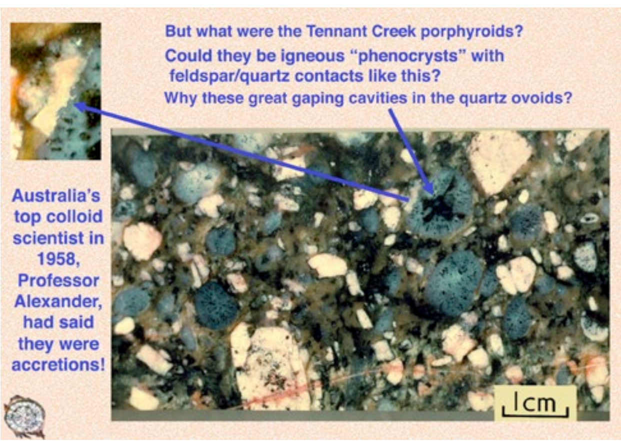


Figure 19. This observation is readily explained as the contact between two soft gelatinous substances such as clay and silica gel. The fragmentation of the feldspars and syneresis in the quartz ovoids confirm their accretionary origin.

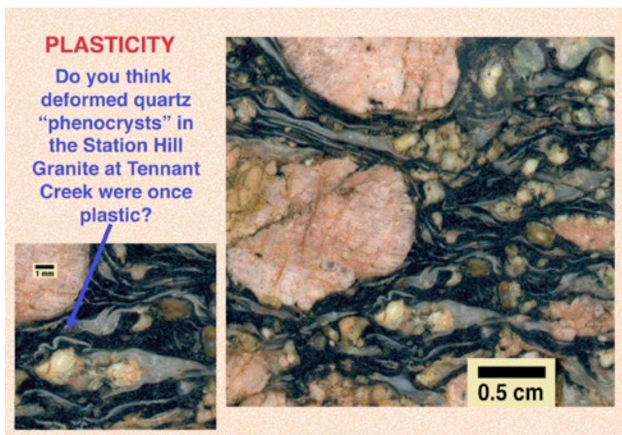


Figure 20. Most geologists recognise that this wispy crystalline quartz in the Station Hill granite at Tennant Creek, Central Australia, was plastic when the granite was fluid. The former plasticity clearly indicates the quartz crystallised from a polymeric silica precursor.

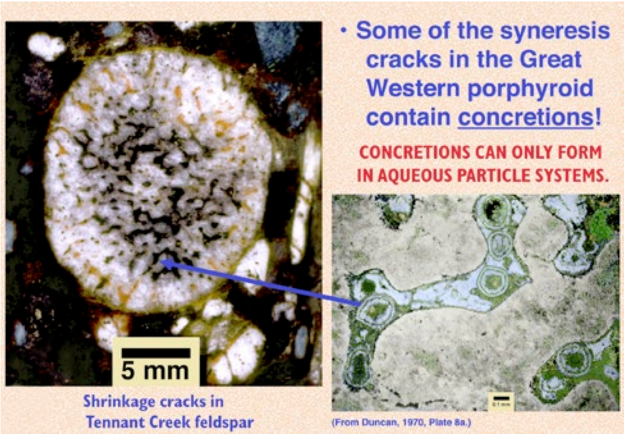


Figure 21. A diffusive gelatinous media is required for the formation of oolites, orbicules and concretions. The occurrence of small poly-rimmed oolites in the shrinkage cracks of ovoidal feldspar from a coarse Tennant Creek porphyroid is positive evidence that the feldspar is a crystallised accretion.

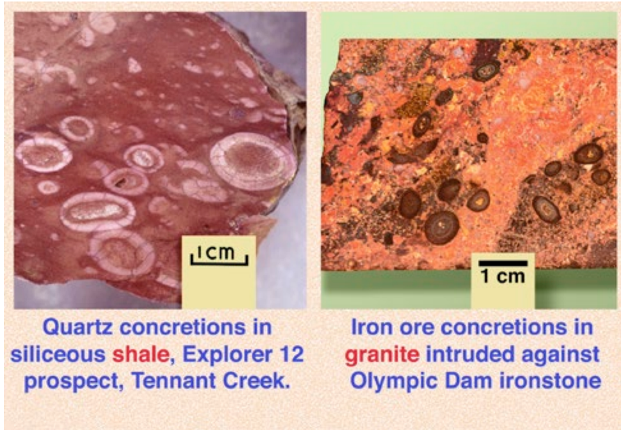


Figure 23. Quartz oolites in siliceous shale from the Explorer 12 prospect at Tennant Creek and haematite oolites in the granite adjacent to the large Olympic Dam orebody in South Australia is further clear evidence that the granite crystallised from diffusive gelatinous precursors.

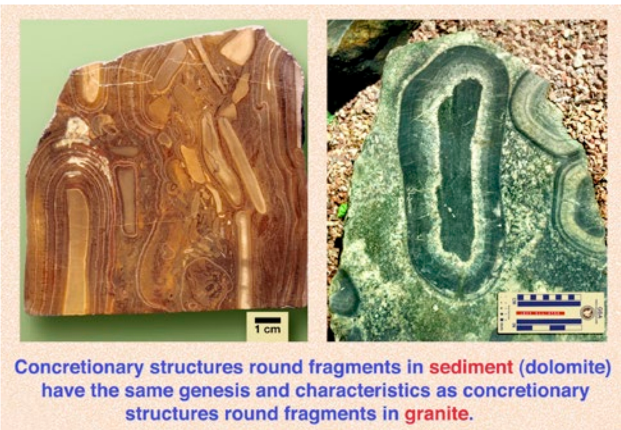


Figure 22. Geologists know that natural sediments like marine mud, lime mud and dolomite are diffusive gelatinous or 'sticky' materials. Orbicules can then form round a synerectic fragment like in this example from Gunpowder Creek in NW Queensland. The formation of an orbicule round a schist fragment in the orbicular granite from Kangasniemi in Finland is clear evidence that the granite crystallised from a diffusive gelatinous precursor.

THE ESSENTIAL INITIAL CHOICE

Today the theory of the origin of granite is maintained by ignorance of alternatives. The granite controversy has persisted in the geological literature and teaching for years but now our knowledge of the materials from which rocks and the mineral deposits they contain are formed is sufficient to fully explain all the features we see preserved in the rocks.

We have a clear and obvious initial choice. We can remain with traditional teaching and beliefs that are still based on James Hutton's observations and conclusions at Glen Tilt in the Cairngorm Mountains in the Scottish highlands in 1785. Figure 25 is Sir Henry Raeburn's 1776 portrait of James Hutton. At that time James Hutton's studies of the granite contacts with the "alpine schistus" established beyond doubt that the granites had once been fluid in relation to the "schistus" they invaded (Figure 26).

In his "Theory of the Earth", 1788, Vol. 3, he writes:

> *Without seeing the granite actually in a fluid state, we have every demonstration possible of this fact; that is to say, of granite having been forced to flow, in a state of fusion among strata broken by a subterranean force, and distorted in every manner and degree....*

An example of the complex mixing of sediment and granite minerals is illustrated in Figure 27.

However, Hutton's *"Theory of the Earth"*, 1788, Vol. 1 does make it clear that this is a provisional hypothesis. On page 39, he acknowledges that this would not necessarily be true *"if there were any other cause for fluidity besides the operation of` heat"*.

Hutton's molten theory of granite has persisted by default. His *"Theory of the Earth"* recognised uniformitarianism by which the rocks are continually eroded and reformed by compaction of the resultant sediments over extremely long periods of time. His "molten rock" theory for granite displaced the theories of neptunism (granite minerals precipitated directly from sea water) but over the 230 years since Hutton the problem of granite genesis remains for those who can only con-

Figure 24. In this group of Australia's top scientists at the CODES symposium in Hobart on 22nd to 23rd of November 2007 are:
*Jacob Rebek***,** Group Chief Geologist, Rio-Tinto Exploration – remobilisation of ore sulphides and sphalerite with hydrocarbons in the ore beds at Century zinc mine.
Dr David Duncan – discovery of small oolites in shrinkage cracks of the clay precursors of feldspars in the Great Western porphyroid at Tennant Creek.
Dr Wally Fander – found the lobate feldspars in the Tennant Creek porphyroids and small oolites in the intrusive basic rocks from the Ranger open pit.
Bob McNeil – found the porphyroid-like shrinkage patterns in quartz accretions in the formerly fluid mud matrix of the True Blue slip complex.
John Love – found orbicules in the norite at the Empress Mine, orbicules in the amphibolite at Copperfield Creek, the micro-granite marker horizon in British Columbia, and saw Termier's fossil in the granite feldspar at the French Academy of Science in Paris.
Rob Ryan – led the recovery of Geopeko staff and operations following Cyclone Tracy and managed the uranium exploration and development of the Ranger ore deposits.
Kim Wright – found the oolites and colloform textures in the Peko Mine and published magnificent examples of the colloform textures and evidence that minerals from Gecko, Peko, Juno, and Ivanhoe mines had been deposited as a paste and sludge of colloidal precipitates.
Professor Dick Stanton – published his magnificent ground breaking 1989 paper containing the information and data that established the precursor principle for metamorphic and granitic rock crystals.
Professor Tom Healy – formed accretions experimentally and led the research that measured interparticle forces with an adapted atomic force microscope.
Professor Ross Large – found the new mineral 'Proudite' in the Juno Ore.
Bob Richardson – devised the world's first radiometric aerial survey system to use a 256 channel spectrometer.
Brian Williams – found large clay accretions in the lit-par-lit granite at Wilson's Promontory that had crystallised to feldspars.
Andy Browne – detailed the geology of the Ranger ore deposits.

sider the problem within the bounds of current teaching and James Hutton's provisional "molten rock" theory for which this ancient and totally inadequate theory is still the basis.

Rocks are refractory and behave like bricks when they are heated. Hutton's provisional hypothesis that granite fluidity was due to melting of the granite minerals continues to pose unresolved problems that are indeed childishly incongruous in the light of current knowledge. Some of these problematic observations are illustrated in Figures 28 to 32.

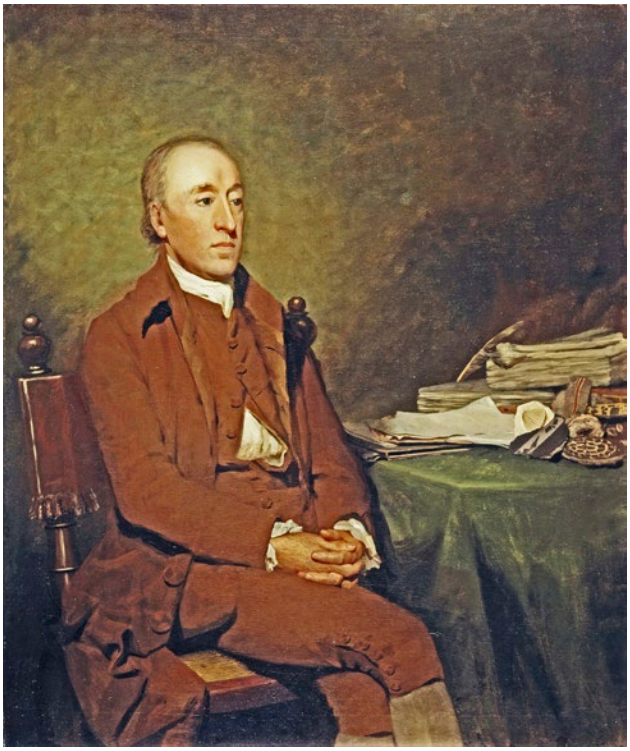


Figure 25. James Hutton 1726 to 1797 (from Wikipedia).

Figure 26. This is the location of Hutton's observations of intrusive granite, Glen Tilt, Scottish Highlands (from Wikipedia).

Figure 27. *"We have every demonstration possible ... of the granite having been forced to flow ... among strata broken by a subterranean force and distorted in every manner and degree ..."* These examples are from West Ava in the Åland Islands, Finland. The thin veins of granite and isolated globular feldspars are inconsistent with high temperature melting

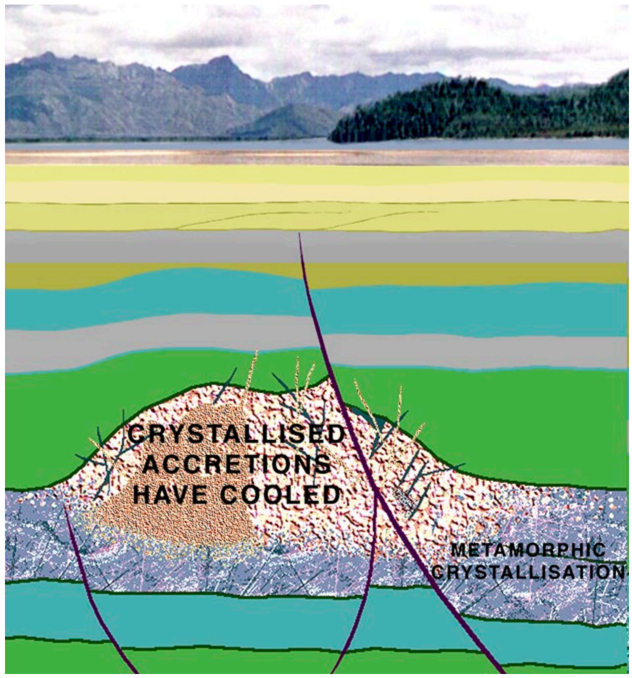


Figure 28. The source of heat including latent heat of fusion that would melt granite plutons remains unknown. Where would the heat come from to selectively melt and re-melt specific large volumes of rock?

Observations relating to granite consistently indicate that this rock was not formed by cooling of a molten rock mass similar to cooling a mass of basalt lava. Palingenesis (repeated fluidity that breaks up previously emplaced dykes), plasticity of granite minerals, 'loopy' irregular (ptygmatic) veins, layers of oriented crystals of biotite and plagioclase (comb layering), re-invasion of previously emplaced plutons without displacement (the room problem), calcite in granite is chemically incompatible, concentrically layered concretions of iron oxide (oolites) in granite are chemically incompatible, chert veins (former colloidal quartz) in granite, and mixing of granite with marginal sediments provide clear evidence of the non-molten origin of granitic rocks.

HUTTON OR MODERN SURFACE CHEMISTRY?

It remains true that rocks and rock minerals cannot assume a fluid condition unless they are melted.

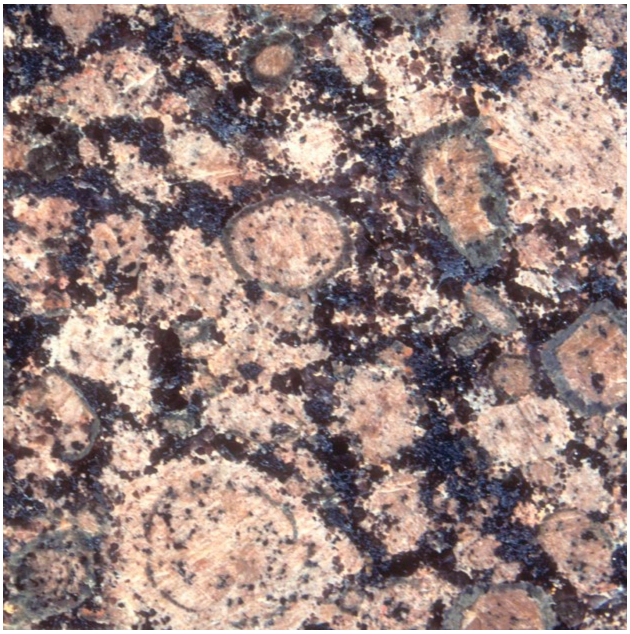


Figure 29. Rapakivi granites are completely inconsistent with melt cooling. They contain large rounded potash feldspars some of which are rimmed or have internal concentric zones of calcic-soda feldspar (plagioclase). Why are the rapakivi feldspars rounded, aggregated and some contain internal or external rims?

Figure 31. Large crystals of quartz and feldspar from the surrounding granite matrix are found embedded in fragments and wall rock. This double-enclosure problem is inconsistent with molten rock theory. The enclosed entities may not have been crystalline at the time of enclosure in the soft fragment or wallrock but general pre-crystalline mobility is clearly indicated.

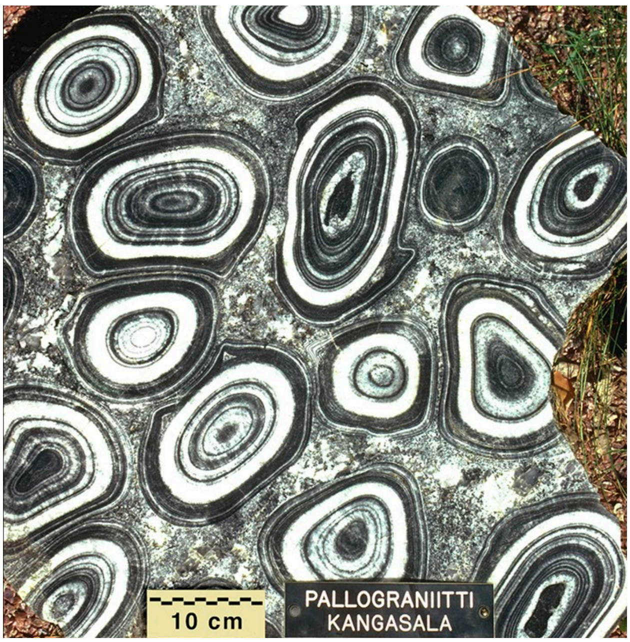


Figure 30. Granites containing orbicules (large concentric spheroids of feldspar and biotite) are simply incompatible with melt cooling. They clearly contradict Hutton's classical molten rock theory. Petrological teaching avoids study or recognition of their existence. Orbicular granites are regarded as a curiosity and the problem of how they are formed is simply not addressed.

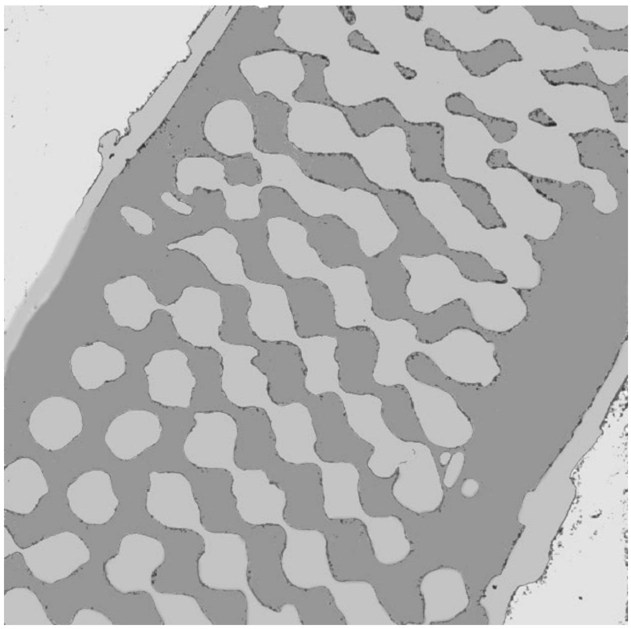


Figure 32. Termier and Termier[4] (1970) found an echinoderm shell within a granite feldspar crystal in the Atlas Mountains in Morocco. It could not have been preserved within any feldspar crystallised from a melt. If the Moroccan granite had been molten when the calcite echinoderm shell was present, it would react to form calcium silicate like the limestone used to flux acidic melts in smelting operations.

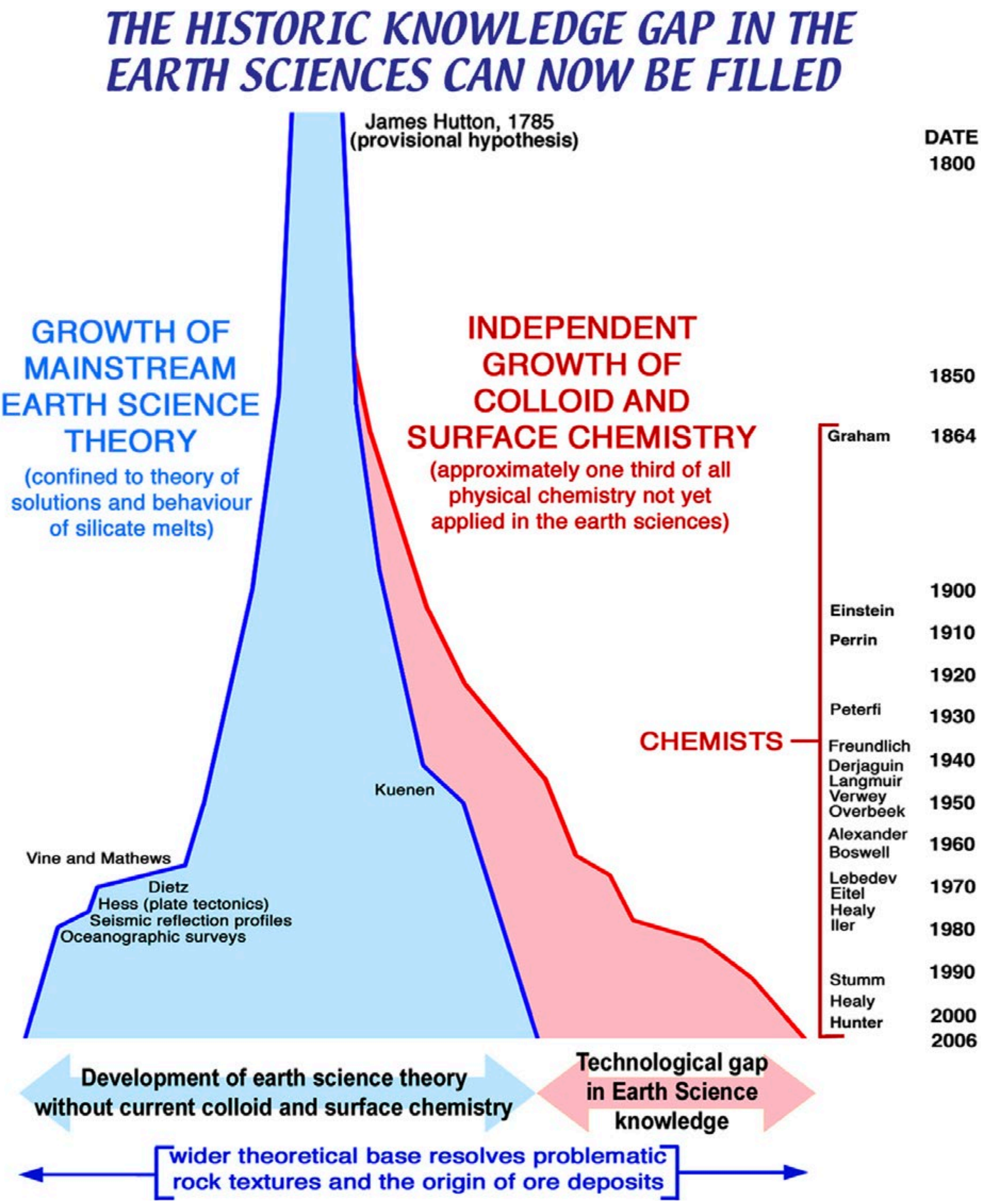


Figure 33. The independent growth of knowledge in the Earth sciences and in colloid science has left a widening gap in our understanding of how rocks and mineral deposits were formed. This can now be filled.

The positive evidence that intrusive granites were not fused rock minerals therefore clearly indicates that at the time of intrusion the common granite minerals, feldspars, biotite, hornblende and quartz must have been some other material that could liquefy, intrude, form rapakivi and orbicular textures, contain fossils, calcite and iron oxide concretions (oolites), chert veins, etc.

Basalts and dolerites have a different composition but the bulk composition of granites corresponds to metamorphic rocks and sediments. For granite batholiths found in the continental rocks of the world then we have to choose between Hutton's 1788 provisional hypothesis or some other means of making the sedimentary materials intrusive (repeatedly in some cases), mobile and able to crystallise to the observed coarse granite ovoids and mineral textures.

Since Hutton we now have the information to demonstrate conclusively that the hydrolysis (chemical reaction with water) of sediment particles, mobility of wet sediments and particle interactions between sediment particles in gelatinous wet sediment pastes can produce all the observed crystalline mineral textures and phenomena. Figure 33 shows the widening gap between the growth of knowledge in the Earth sciences and the developments in the physical chemistry of small particle systems. This additional knowledge can be used to understand the origin of rocks and mineral deposit and observations that have been problematic until now.

WE CAN NOW RELY ON EXISTING KNOWLEDGE FROM OTHER DISCIPLINES

Sediment Mobility

The information on mobile sediments has been available for over 50 years but the physical and chemical properties of wet sediments remained unknown for about 175 years after publication of James Hutton's "Theory of the Earth". Oceanographic surveys and both onshore and marine seismic reflection profiles now show the large-scale sediment liquefactions and intrusions as illustrated in Figures 34 to 39.

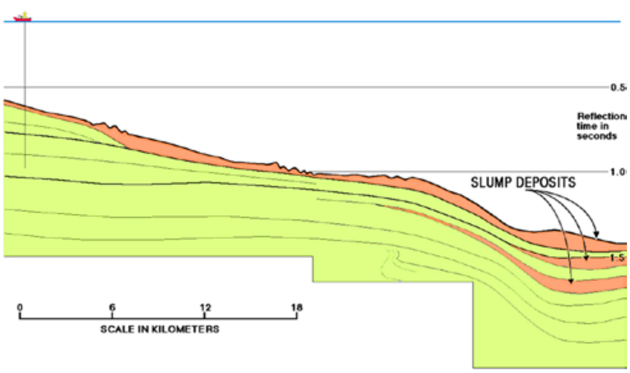


Figure 34. Massive submarine slope failure involves liquefaction of large volumes of sediment. Lehner[12], 1969, fig. 45.

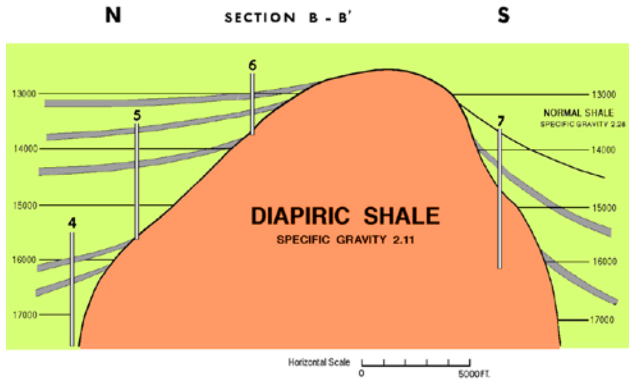


Figure 35. This intrusive shale mass is near Eugene Island, Texas gulf coast. Gilreath[13], 1968, fig. 9.

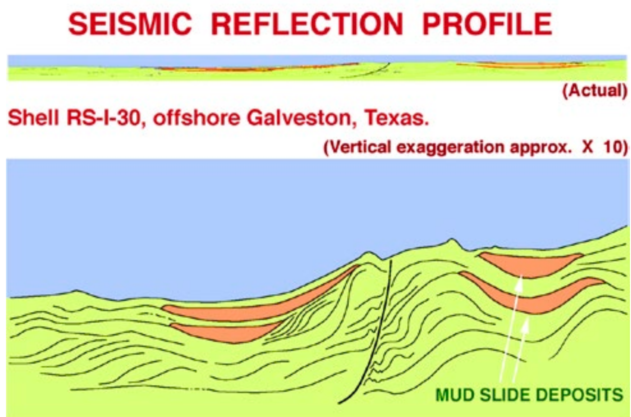


Figure 36. A Shell reflection profile reveals large volume mudslide deposits offshore Galveston, Texas. Wilhelm and Ewing[14], 1972, fig.11.

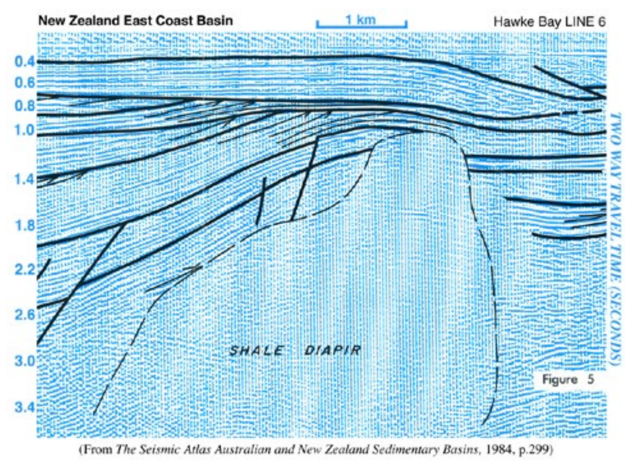


Figure 37. Seismic surveys[15] record a large intrusive shale mass in Hawks Bay, New Zealand.

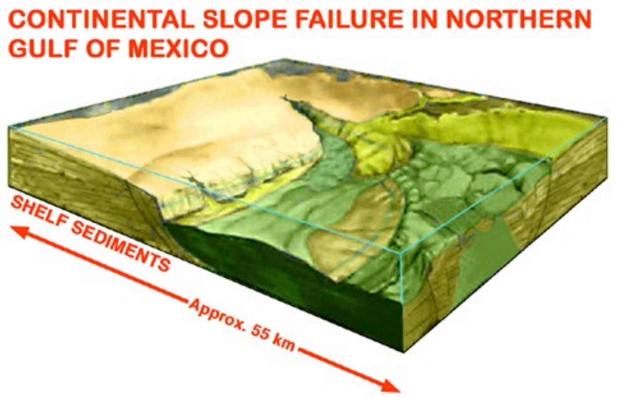


Figure 38. Liquefaction and displacement of large volumes of wet sediment result from submarine slope failure.

Figure 40. Think of the energy required if cavernous natural valleys were excavated by open cut mining methods (or by ancient quarrying methods before the advent of explosives and mechanical earth moving equipment).

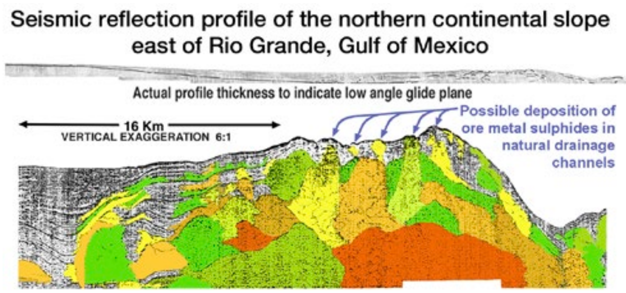


Figure 39. Seismic reflection profiles reveal a thickness of shelf sediments 900 to 1200m thick built up from successive earthquake shocks and downslope sliding. The water-rich and lighter thixotropic buried sediments have then risen as complex of large sediment diapirs through the accumulated slump deposits. (Wilhelm and Ewing[14], 1972, fig. 9.)

PHYSICO-CHEMICAL UPDATE OF SEDIMENT COMPONENTS

Seismic surveys and drilling establish the large and small scale mobility and intrusion of sediments but we have also to consider the chemistry and surface chemistry of the trillions of particles that make up the deep sediment accumulations from which the rocks and mineral deposits are formed.

The physical breakup of the rocks and rock minerals in the cycle of sedimentation is obvious. The immense energy inputs to achieve the physical excavation of the natural valleys as in Figure 40 and the chemical energy to breakdown and change the rocks and rock minerals must be appreciated.

The slow physical and chemical breakdown of the rocks to boulders, scree, cobbles and soil and its transport downstream to finally discharge from the river mouths on to the continental shelf all require physical and chemical energy inputs.

A major chemical change in the environment of natural sediment particles occurs as they enter the sea. Organic matter, soil acids, air-ground water changes, etc. are replaced by very long periods of soakage in slightly alkaline seawater.

The rocks and rock minerals exposed on the land end up as massive accumulations of high-energy particle systems as illustrated in Figure 41. They comprise the continental shelves where further submarine erosion results in the deep marine deposits.

The basic sediment particles are clays, silica and hydrous ferromagnesian minerals but every sediment layer differs in proportion of these components and a variety of organic, carbonate and other lesser components that characterise marine muds. The sediment particles flocculate and precipitate to compact as random aggregates of mixed particles as illustrated in Figures 42 and 43.

HYDRATED SEDIMENT PARTICLES BECOME PRECURSORS OF THE NEXT GENERATION OF ROCKS AND MINERAL DEPOSITS

The essential basis of the cycle of weathering, sedimentation, sediment mobility and compaction to the next generation of rocks and mineral deposits is well understood by everyone. However, an alternative to Hutton's provisional "must have been melted" theory requires the chemistry and behaviour of the high-energy charged particles to be considered.

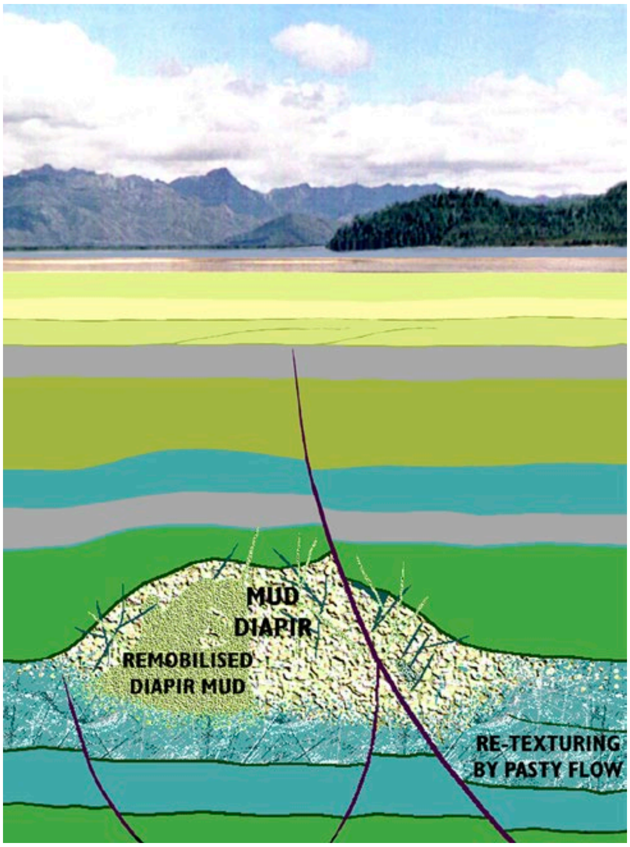


Figure. 41. Accumulated sediments contain re-mobilised sediment lenses and diapirs.

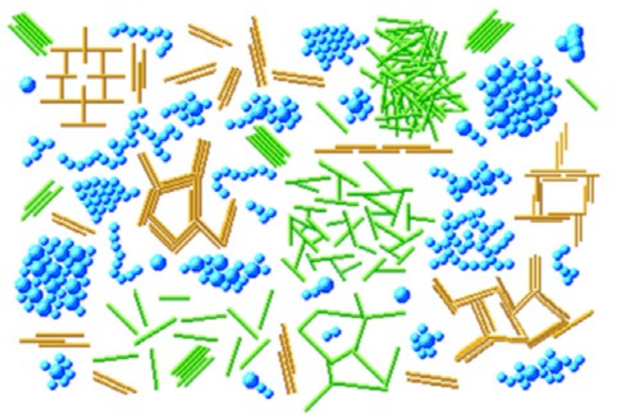


Figure 42. Natural sediment particles are attracted to each other by surface charge to form clusters and particle associations when they first precipitate.

The basic chemical reaction of "weathering" occurs mainly under the sea. The endothermic hydrolysis of the silica and silicate surfaces creates silanol groups (Si-OH) on the surfaces as indicated in Figure 44.

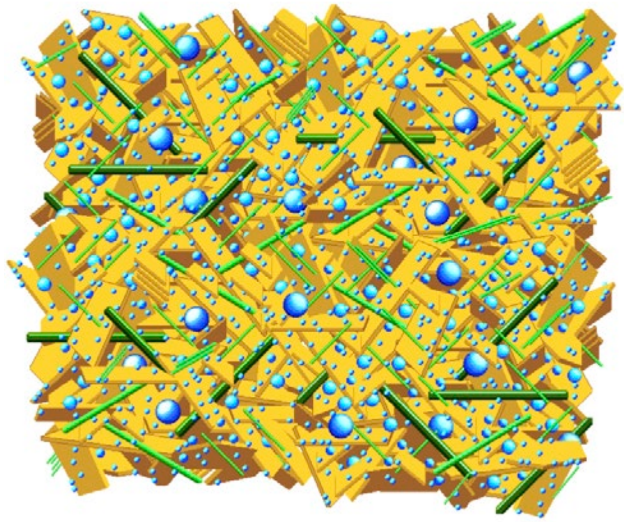


Figure 43. Initially flocculated sediments compact to a relatively random initial aggregate of mixed particles.

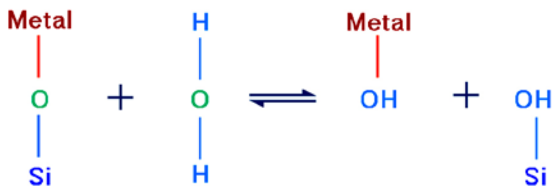


Figure 44. Sediment particles are hydrated metal silicates such as clays. These are mainly potassium or Na-Ca alumino-silicates that hydrolyse further in seawater.

Clays predominate at about 65% of the sedimentary material, silica is usually about 20% and hydrous ferromagnesian and other components make up the rest. Natural sedimentary systems are complex but we have to consider the physical chemistry and fluid properties of small particle systems to understand how all the observed features are simply explained.

Quartz is not the main component of granitic or porphyritic rock (about 20%) but it is the simplest chemical compound and quartz veins are the most common of all mineral deposits.

When 'solubility' is defined as the dispersion of an anion and cation into the solvent, quartz is not soluble in water. Weathering processes, soil acids and stream transport leave the sand grains unchanged chemically but deposition in slightly alkaline sea water hydrolyses silica surfaces as shown in Figure 45.

Silica Hydrolysis

Silica gels therefore disperse in water to form three types of dispersion:

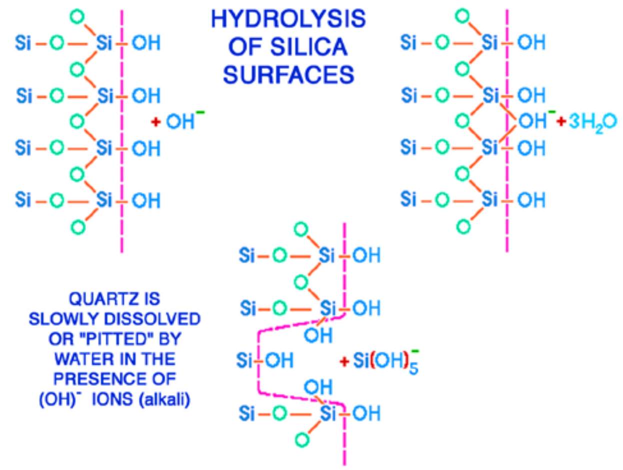


Figure 45. The dispersion of solid silica in water is catalysed by hydroxyl ions such as an alkali or base. Seawater is slightly alkaline and therefore silica (and most silicate) surfaces "dissolve" by these surface reactions. (Redrawn from Iler[8], 1979, fig. 1.11.)

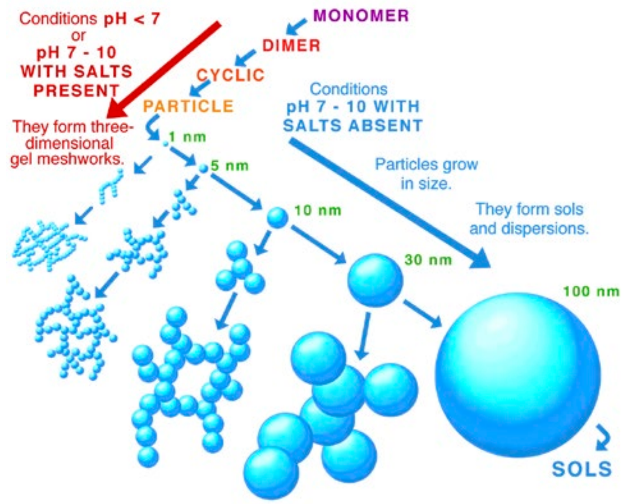


Figure 47. This diagrammatic representation of the growth of natural silica particles is re-drawn from Iler[8], 1979, p. 174.

i) simple monomeric complexes such as $Si(OH)_4$ aq.

ii) oligomers or polynuclear complexes such as $Si4O_6(OH)_6^{2-}$ which represent condensed chains of $Si(OH)_4$ tetrahedra.

iii) poly silicic acid where very long chains are produced with cross-linking to yield partly condensed three dimensional networks.

Basic Reaction for Silica Polymerisation

Figure 46. The basic reaction by which hydrated silica polymerises is divestment of water to form siloxane linkages.

HYDRATED SILICA – SI(OH)$_4$ – GROWS TO "LITTLE BALLS"

Monomeric silicic acid is a small non-ionic molecule that is dispersed at low concentration in seawater itself and at higher concentrations within the sea-floor mud. The growth of the polymeric particles depends on pH and salts present. Particles of silica gel form chains and particle structures because the charged particle surfaces interact with each other. The development of silica globules is indicated in Figure 47.

Chains and 'structures' of natural polymeric silicic acid are formed by interaction between the surface charges on the gel globules.

Clay Hydrolysis

Clay hydrolysis begins in the weathering profile and continues within marine sediment accumulations. Clays are structured macromolecules with a wide variety represented in natural sediment accumulations. The example of simple three-layer clay in Figure 48 indicates the basic hydrolysis reaction. This equilibrium with clay minerals applies generally but if the material is sheared when fully hydrolysed metal hydroxide is released from the interlayers.

Clays, silica gel and hydrous ferromagnesian minerals are the main components of sediments that con-

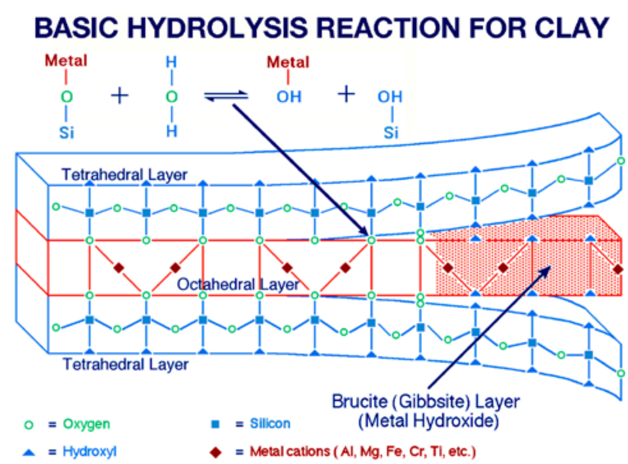


Figure 48. The external surfaces of natural clay platelets are fully hydrated. In the marine environment, further hydrolysis can therefore only progress inwardly from the edges of the platelets (within the octahedral layers).

solidate to rocks. The common hydrous ferromagnesian minerals are chlorite, chamosite and glauconite with lesser amounts of variably hydrated species like antigorite, phlogopite, talc, kaolinite, steatite, allophane, epidote, anthophyllite, greenalite, attapulgite, etc.

Characteristically, the ferromagnesian minerals are highly hydrated. They tend to retain the water of hydration and therefore maintain their mobility as gelatinous slimes and oozes until later in diagenesis and burial. They remain 'oily' during the accumulation of sediments in marine basins.

The 'sticky' gelatinous nature of marine mud is due to its content of clay and polymeric silica gel.

The Precursor Principle

It is a simple fact that mud, a heterogeneous macromolecular mixture of interacting high-energy hydrolysed particles is the material from which rocks and mineral deposits are formed. The properties of these precursor materials provide an understanding of the features and textures observed in the rocks and the way in which the various types of mineral deposits were formed.

Normally gelatinous and then with various stages of increasing rigidity as chemical dehydration reactions increase and chemical bonds establish between particles, the main properties of sediment accumulations during diagenesis are: -

1) The fluid properties plasticity, liquefaction by shaking and rapid re-setting at low rates of shear (thixotropy and rheopexy). Bulk sediments can deform or become contorted plastically, liquefy by earthquake shock and rheopexy, accelerated re-setting at low rates of shear preserves the form and content of a liquefied sediment mass.
2) Separation of more fluid components (rheological separation) is the important mechanism whereby the content of more mobile components such as liquid silica gel, ferric hydroxide, clay, chlorite, etc. simply run out of disturbed sediments or an accumulated mineral mass. They form veins and intrusive bodies.
3) Diffusion and diffusion gradients. Ions and very small particles dispersed in pore fluids can diffuse in precursor sedimentary material. Precipitation on a nucleus or surface creates a diffusion gradient for more particles to diffuse to the precipitation point.
4) Accretion is the dynamic aggregation of particles of similar shape into a denser close packed cluster at net lower surface energy. Crystallisation of these pre-ordered aggregates subsequently occurs to form a 'porphyroblastic' or granitic textures.
5) Concretion is the slow or step–wise accumulation of material about a central nucleus to produce a banded–textured spherical or elliptical accumulation of higher particle density and compaction than the surrounding medium. The active process of concretion depends on colloidal particles individually diffusing towards the precipitating surface. Precipitation at this surface is a consequence of a marked change in electrolyte concentration that is produced within the denser gel nucleus. Orbicules form in pre-crystalline granite in this way.
6) Synerectic desorption. Within close packed particle aggregates such as accretions and concretions particles are drawn together by van der Waal's strong forces of attraction at very close interparticle separation. Total surface energy is lowered and internal surface and adsorptive capacity are reduced. Species adsorbed on surfaces are desorbed. Polar water molecules, ions, and smaller charged particles are exuded from the clusters into the matrix brines. This results in discharge to the pore fluid brines of exceedingly small metal hydroxide and hydroxy-sulphide particles
7) Critical cluster. As a precipitate begins to form initiation of the solid phase is achieved by chemical reaction between ions or molecules that would lead to the formation of a solid phase. Where the reacting substances are at low concentration or the reaction is controlled by diffusion rates, this leads to the formation of a critical cluster or nucleus that has special properties at the point where a liquid-solid interface is first formed. The extraordinarily high surface energy of such nascent nuclei or critical cluster of molecules is sufficient to dissociate water molecules. Hydrolysed critical clusters can diffuse through the finest openings

STUDY OF PRECURSOR SEDIMENTS NOW RESOLVES THE ORIGIN OF GRANITE AND MINERAL DEPOSITS

Figures 49 to 61 are selected from presentations at the CODES symposium at the University of Tasmania in 2007. The participants considered the topics under each heading and annotations and explanations draw attention to the photographs and diagrams in each figure. They were recognised as compelling evidence for the formation of accretions in flow-sheared sediment and their subsequent crystallisation to rock minerals.

Over 60,000,000 Square Meters of Surface Area in Every Cubic Meter of Natural Mud

- All chemical reactions that occur in inter-particle spaces of fine-grained sediments during diagenesis must take place in the immediate vicinity of a surface.
- Hydrothermal solution theories are based on normal chemical reactions established for bulk solution such as those in open test tubes or laboratory reaction vessels.
- The presence of charged surfaces at the scale of the reacting ions and molecules is the essential difference between what actually happens in nature and "hydrothermal solution theories".

Figure 49. There is an essential difference between what happens in nature and historic geological theory.

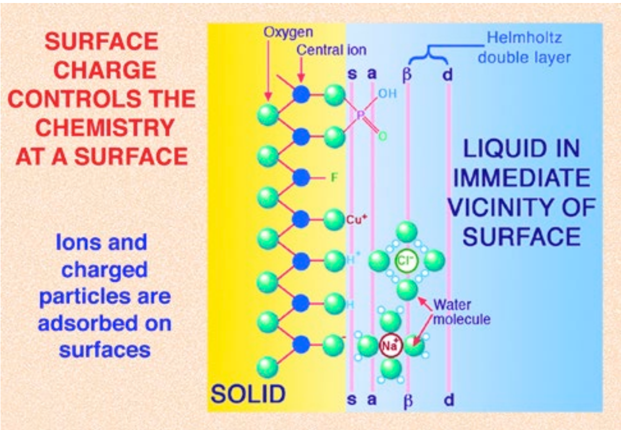


Figure 50.

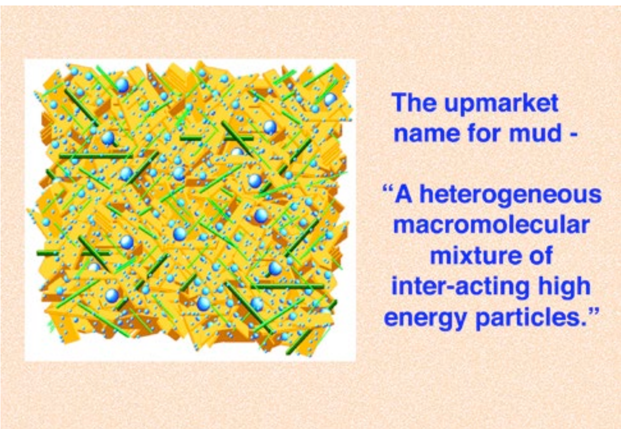


Figure 51.

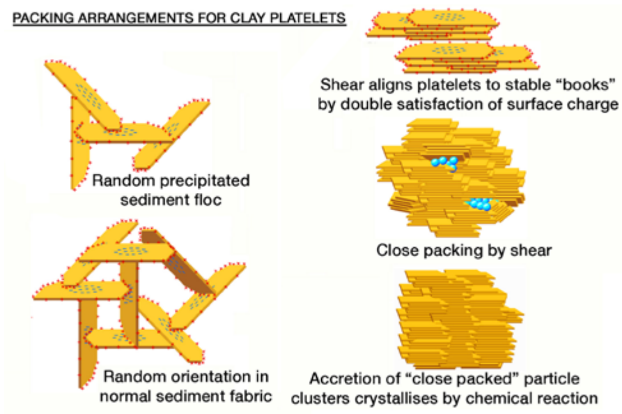


Figure 52.

Experimental Evidence for the Formation of Accretions

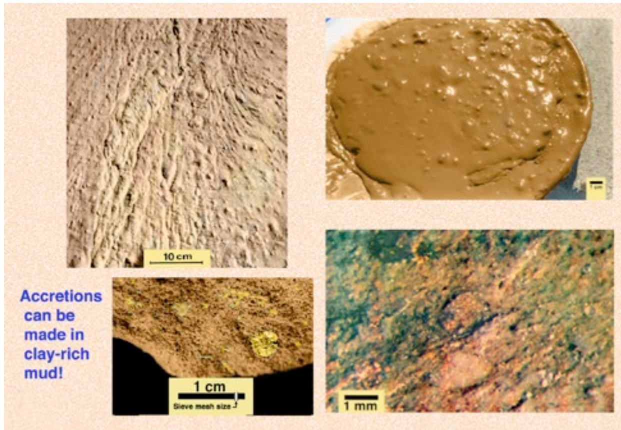


Figure 53.

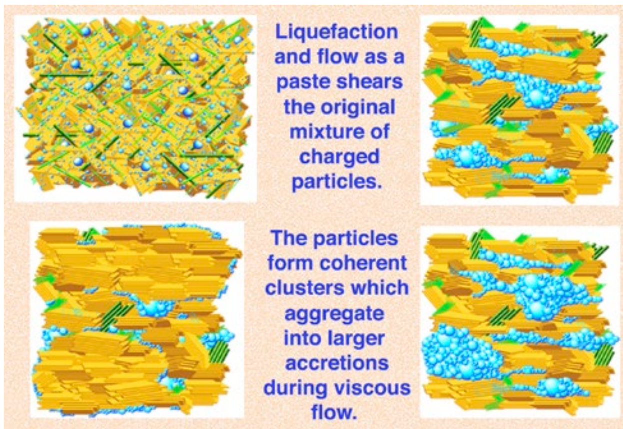


Figure 54.

Drill Core and Microscope Evidence for the Formation of Accretions

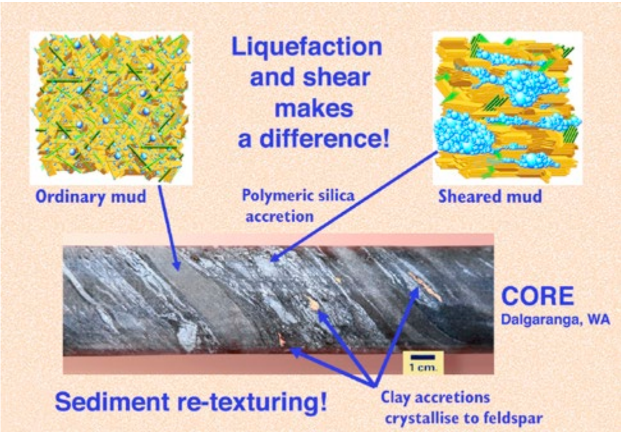


Figure 55.

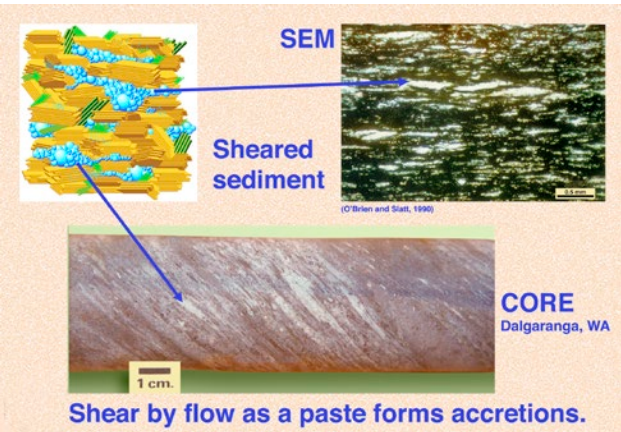


Figure 56.

The Formation of Accretions Is Clearly Related to Shear and Pasty Flow of Precursors

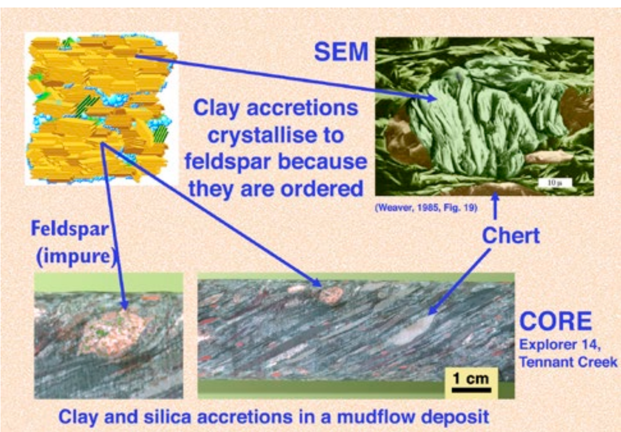


Figure 57.

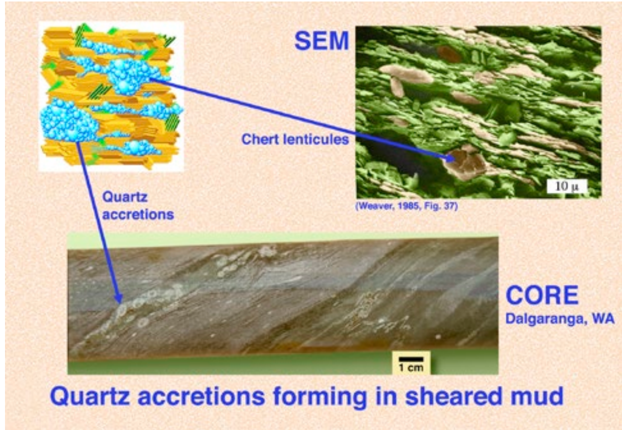


Figure 58.

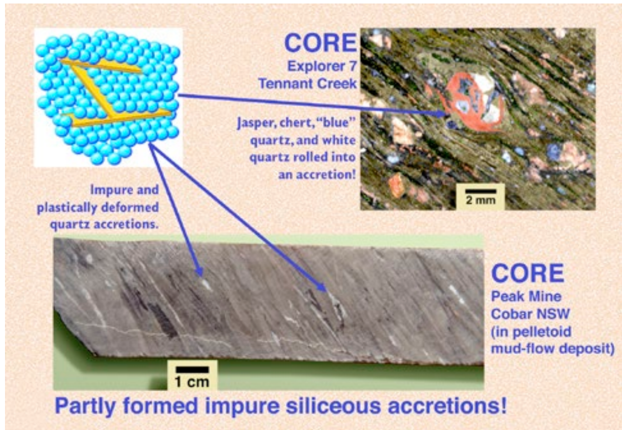


Figure 59.

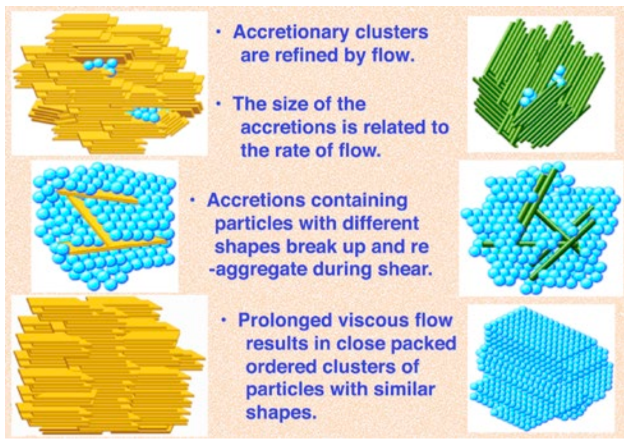


Figure 60.

In Principle the Precursors Crystallise to Porphyroid, Metamorphic and Granite Minerals

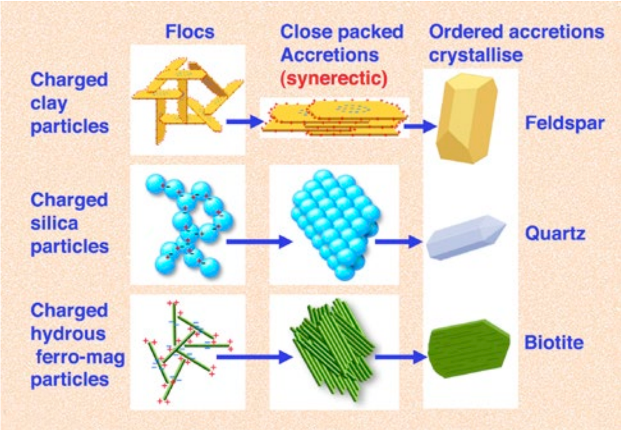


Figure 61.

RECOGNITION OF THE PRECURSOR PRINCIPLE

Wet chemically degraded sediment particles are the materials from which rocks and mineral deposits are formed. Recognition of the precursor principle means recognition of both the bulk behaviour of sediments at various stages of consolidation and details of the surface chemistry and physico-chemical properties of the trillions of particles.

These properties include cohesion and fractural nature, plasticity, liquefaction and re-setting (thixotropy and rheopexy), viscosity varying with the rate of shear (shear thinning), diffusion, adsorption and desorption of ions or charged particles on surfaces, concentric precipitation round a nucleus (concretion), particle aggregation to more ordered clusters (accretion), auto-shrinkage of particle clusters (syneresis), chains and structures of charged particles (long-range ordering), and enhancement of crystal growth.

Small particle systems may seem complex because natural sediment particles range in size from a few nanometres (molecular and macromolecular) to about 1,500 nanometres. Particle sizes vary over four orders of magnitude and although natural sediments are basically clays, polymeric silica and hydrous ferromagnesian minerals, there are many other components. Physical disturbance of accumulated sediments triggers chemical reactions and particle interactions and re-adjustment by diffusion of ions and small particles.

Recognition of the precursor principle now accounts for all the observations. Larger-scale folding, liquefaction and intrusion, rheological separation of the sediment components and details of observed textures such as porphyroids, granites, rapakivi texture, orbicules, concretions, syneresis crack patterns, framboids, myrmekites, oscillatory zoning, oolites, opal, ptygmatic veins, geodes, double enclave, palingenesis, etc. are all explained. Everything does fit neatly into one system.

Energy considerations and observations are explained in the treatise *"The Origin of Rocks and Mineral Deposits - using current physical chemistry of small particle systems."* However, the surface chemistry and particle interactions by which most ore deposits are formed needs some explanation.

Porphyroid Feldspars are Typically Rounded, Impure and contain Syneresis (Shrinkage) Crack Patterns

Figure 62. Recording clear observations resolved the problem of composite, plastically deformed, rimmed, "spongy", bent, broken, joined together again, rounded and apparent shrinkage crack patterns in the feldspars of the Tennant Creek porphyroids. Why do these feldspars have features so very different from their normal angular crystal habit? Why do they contain internal crack patterns? Logical deductions from hundreds of observations has provided answers and defined the origin of these rocks and the mineral deposits associated with them. These feldspars have crystallised from ordered but impure accretions of clay that formed when the sediments were mobilised.

Rounded Impure Quartz Accretions Occur in a Variety of Mobile Sediments

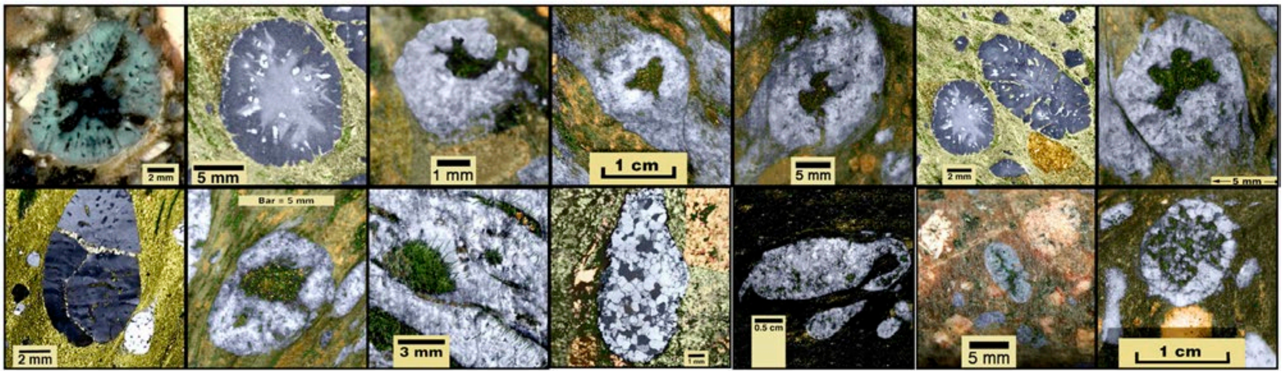


Figure 63. Polymeric silica accretions from Great Western porphyroid, Tennant Creek, have crystallised to quartz.

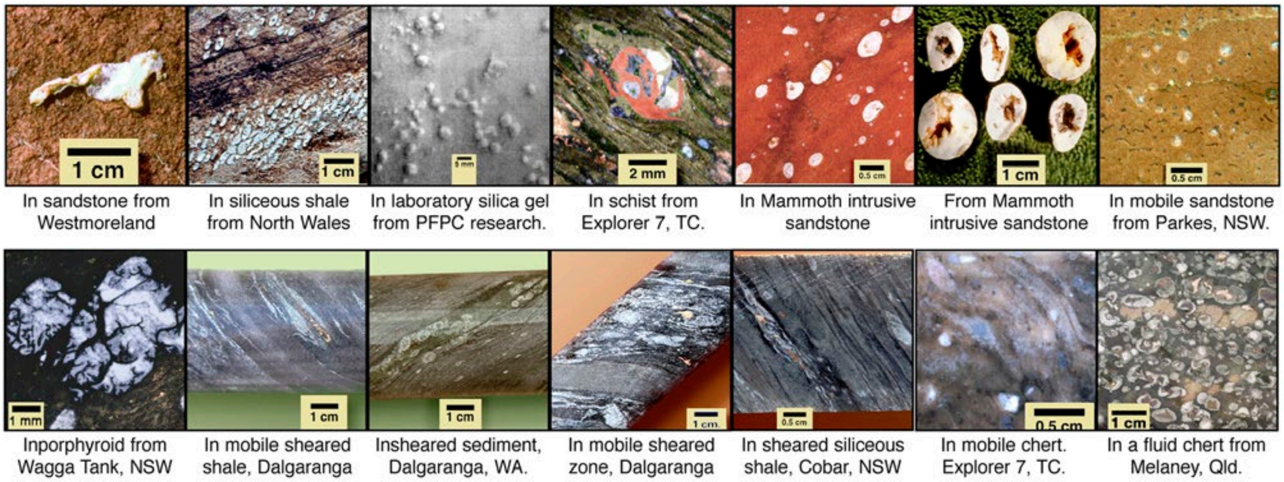


Figure 64. Fourteen examples of silica accretions developed in other locations and contexts are illustrated.

Trace Metals Are Very Sparsely Dispersed in the Soils, Streams and Sediments

The metal ions are transported in stream and ground water systems as ionic species (Figure 65) until they are adsorbed on clays or other sediment substrates (adsorptive surfaces) such as organic materials, metal hydroxides, etc. as in Figure 66. Stream and river waters 'lose' their trace metal ions particularly di- and trivalent heavy metal ions, to the muddy water (particulate species suspended in the stream water).

Mobility and Close Packing Is Required to Release Trace Metals

The systematic search for new orebodies begins with recognition of an ore-forming environment. This was proven successful at Tennant Creek, Parkes, and Kakadu and shown to apply at Cobar, Stuart Shelf, Tanami, Mt. Hope, NW Queensland, and western Tasmania.

Aerial geophysical survey and regional geology can be used to focus on most prospective areas for a portfolio of anomalies to be investigated. The strength and nature of the magnetic, gravity, seismic, radiometric, hydrothermal alteration, and geochemical anomalies give some indication of their possible importance but their relation to the underlying geology and particularly to any indication of synerectic porphyroids is of paramount importance in selecting priorities for drilling.

Favourable source rocks are not necessarily those that have the largest accretions. Trace metal content and nature of the original sediment are important. Repeated mobilisation and re-texturing should not have progressed too far towards completely crystalline granite.

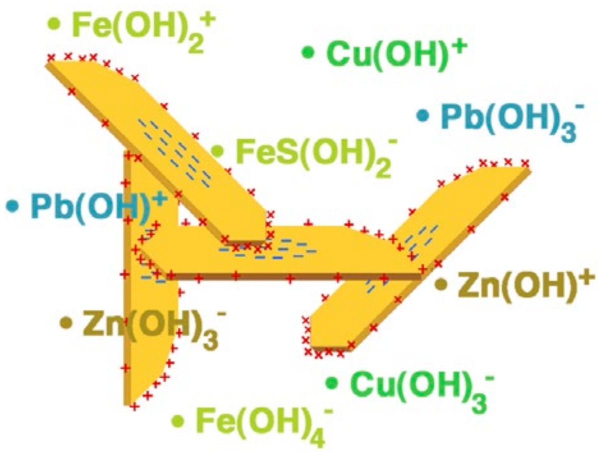


Figure 65. Trace metals are dissolved and leached from soils and rocks by weathering processes. This diagram illustrates a dispersion of hydrolysed metal ions with a simple clay floc but many different particles and surfaces adsorb metal ions from stream water.

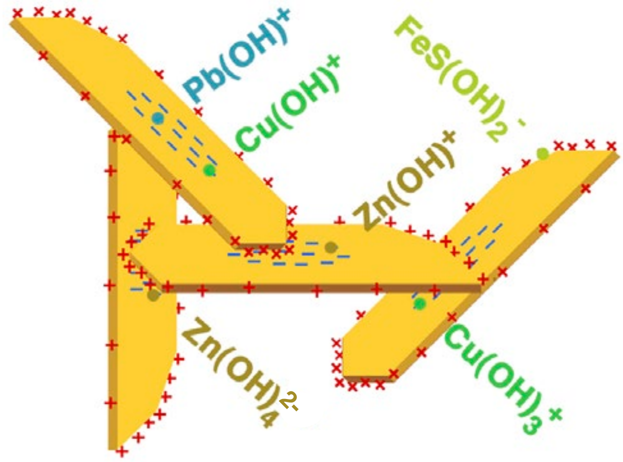


Figure 66. Metal ions hydrolyse or form complexes with water in solution. Charged ions and complexes are removed from solution by adsorption on sediment substrates such as clays, amorphous silica, and organic matter.

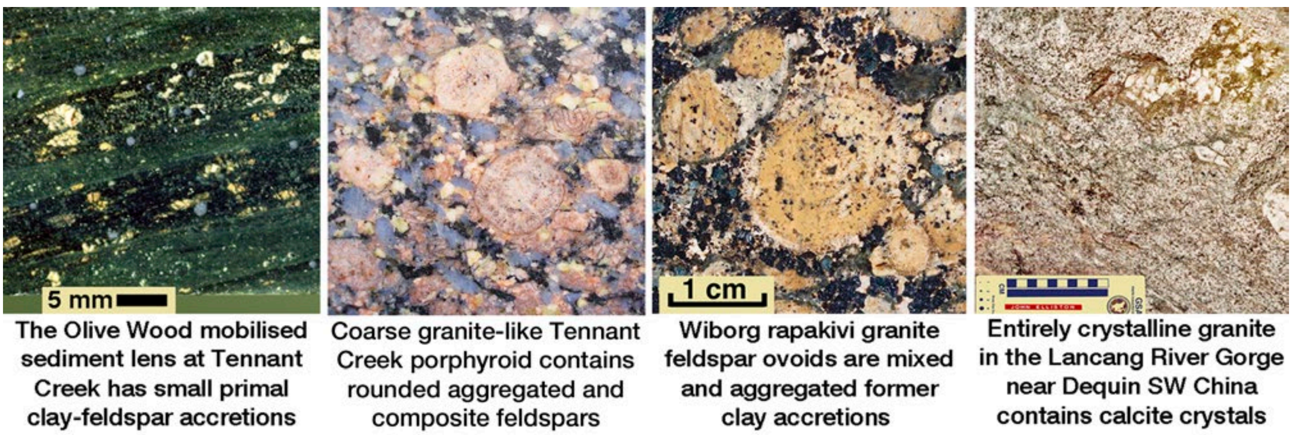


Figure 67. Sediments re-textured by former mobility grade from primitive small clay-quartz porphyroids to crystalline granite.

Figure 67 illustrates a gradation of porphyritic textures from primitive clay-feldspar accretions to crystalline granite. Coarse porphyroids are the most prospective source rocks but crystallisation of granite can result in concentrating some rare earths, tin, molybdenum, lithium, beryllium, etc.

Recent detailed seismic and gravity surveys at north Parkes, NSW, have shown that the several large low-grade near vertical copper-gold pipe-like ore bodies being mined were formed in a similar multiple porphyry intrusion environment to that revealed by the Rio Grande survey in the Gulf of Mexico illustrated in Figure 68.

The Cadia deposits near Orange could be similar and the limited data at Wagga Tank near Mt. Hope is also indicative of a similar environment.

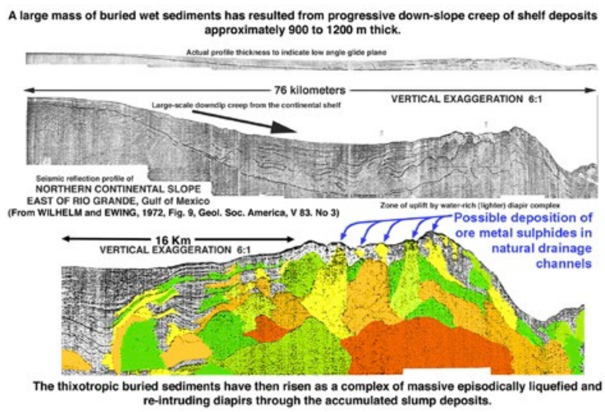


Figure 68. Many rock formations contain porphyroid complexes and granite batholiths formed by a succession of intrusions. Synerectic porphyroids in the rocks are prospective ore source rocks.

Obvious Syneresis Cracks in Feldspars Indicate a Favourable Environment for Ore

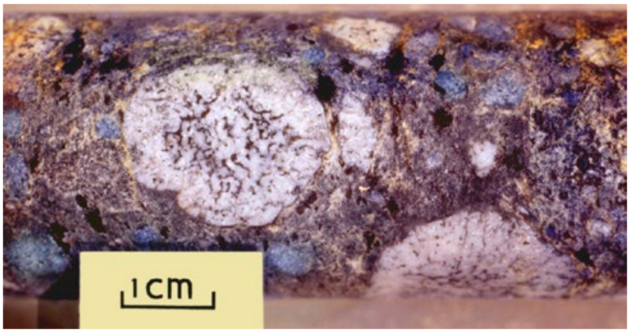


Figure 69. Syneresis shrinkage patterns in Tennant Creek coarse porphyroids have associated orebodies.

Figure 70. Syneresis shrinkage in coarse porphyroid from Wagga Tank, NSW, may indicate associated ore.

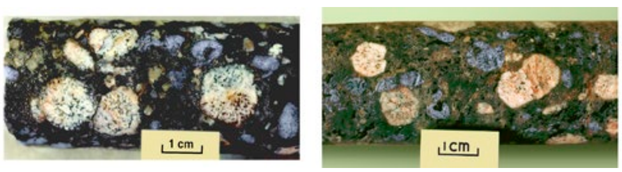


Figure 71. Syneresis shrinkage crack patterns from the precursor clay accretions are preserved in the feldspars of the Great Western porphyroid at Tennant Creek. Figure 69. Syneresis shrinkage patterns in Tennant Creek coarse porphyroids have associated orebodies.

The Physico-Chemical Mechanisms for the Formation of Sulphide Ore

In ordinary basin sediments, the ore-forming base metals and gold are sparsely distributed. Typical ore metals like zinc have a concentration about 110 parts per million, copper is usually dispersed at 60 to 70 ppm, and lead occurs at only some 18 ppm. These divalent ions are spread sparsely at isolated and separate adsorption sites over the very large sediment grain and particle surfaces available to them.

All the surface adsorbed metallic species are exposed to HS^-, which reacts readily with the hydrolysed and adsorbed ions of the heavy metals and iron.

The exposure to sulphidation when diagenetic conditions change to anoxic brings about a great simplification. A wide range of hydrous and surface adsorbed complex metal species are the potential reactants with sulphide ions, but the base metal ions and complexes all form sulphides.

The powerful chemical reaction converts metal ions adsorbed on sediment particles:

$$Me^{2+} + HS^- \rightarrow MeS + H^+$$

This predominates over the many hydrolysing reactions and surface hydration interactions. In the reducing environment, the metal distribution is controlled by this formation of insoluble sulphides. From mobilised sediments containing accretions syneresis and exudation of fluids results in seepage of extremely dilute insoluble metal sulphide molecules dispersed in pore fluid until the insoluble metal sulphide or oxide molecules can coalesce to establish an interface between and liquid and solid to form a particle with sufficiently energy to dissociate water molecules. Precipitation is initiated by:

$$j\ MeS + (2j+2)\ H_2O \rightarrow [(MeS)_j{\bullet}(OH)_2{\bullet}2jH_2O_{ads}]^{2-} + 2\ H^+$$

where j is the unknown number of molecules required to form a critical cluster.

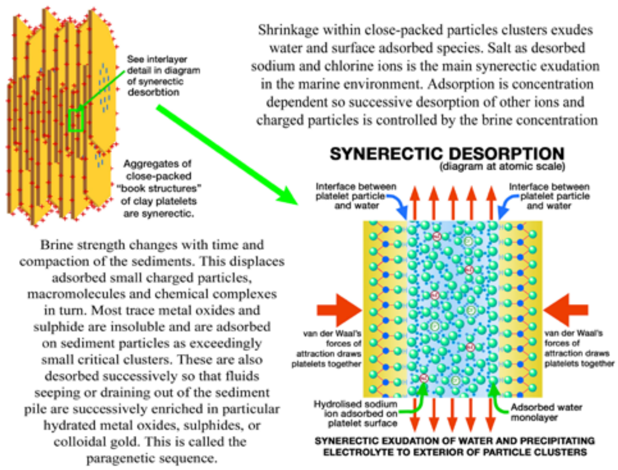


Figure 72. Shrinkage within close-packed clusters of sediment component such as clay accretions exudes water and surface adsorbed minute hydrated sulphide or oxide particles called critical clusters. These are desorbed into the fluid phase and are small enough (8 to 15 Angstroms) to diffuse out through very small sediment pores. Salt is desorbed as sodium and chlorine ions and it is the main component of fluid exudation from marine sediments. Adsorption of other species is controlled by the brine concentration. Adsorption is dependent on concentration and small charged particles cannot compete for adsorption sites at high concentration of Na^+ or Cl^-.

Where volumes of sediment have been re-textured (converted to close-packed accretions) the exudation of insoluble trace metal sulphides and oxides is spontaneous as indicated in Figure 72.

Mobility Followed by Close-Packing of Particles Is Required to Release Trace Metals to the Fluid Phase

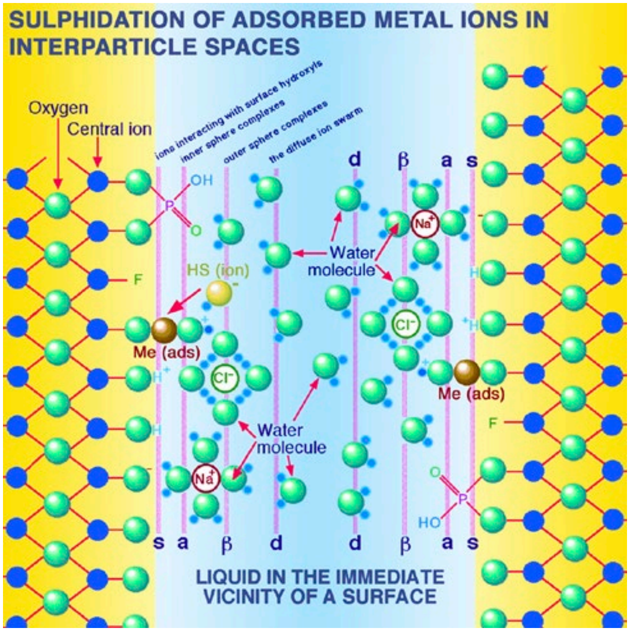


Figure 73. Metal sulphides are formed "molecule by molecule" as soon as buried sediments encounter hydrogen sulphide generated by the bacterial reduction of sulphates. In tidal flats and mangrove swamps reducing conditions (sulphidic) occur a few centimetres below the sediment-water interface but basin sediments generally are anoxic from a few meters below the sea floor.

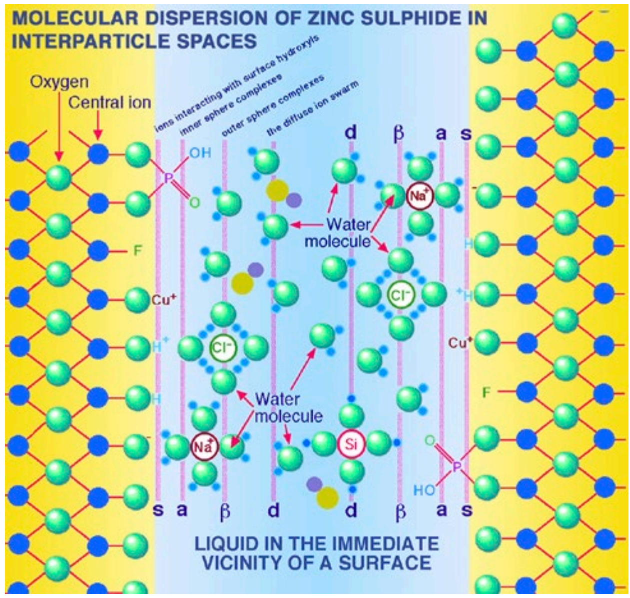


Figure 74. The chemical reaction between hydrogen sulphide ions in pore fluids and trace metal ions adsorbed on sediment particle surfaces "liberates" metal sulphide molecules into the fluid phase. Diffusion controls the rate at which the exceedingly dilute dispersion of molecular zinc sulphide species (represented as tan and blue-grey dots) can begin to nucleate to the solid phase. Nucleation of a critical cluster develops as a particle at maximum surface energy. This dissociates water and combines with it chemically (chemisorbs) to form a hydroxy-sulphide.

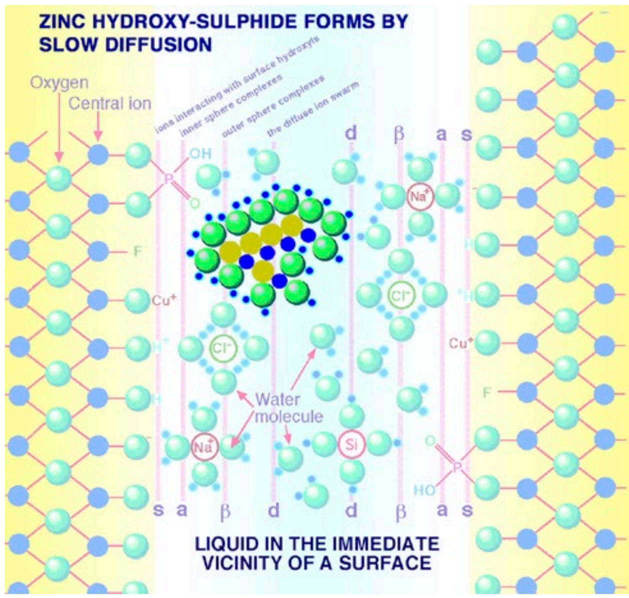


Figure 75. The initial solid phase of zinc sulphide precipitate is too small to be seen by SEM. In this diagram it is depicted as a hydrated nucleus surrounded by adsorbed water molecules. The oxygen atoms in this surface water are two hydrogen atoms short of those required to hydrate the cluster entirely with water molecules. The actual atomic geometry and hydration of a molecular cluster of this nature is quite difficult to determine and it is probably variable. It is quite important that some of the water molecules are dissociated. Hydroxyl groups have reacted with some or all of the high-energy lattice sites.

Stages of Fluid Release Are Related to Pore Fluid, Surface Adsorbed Water and Chemically Combined Water

Stages of fluid release from compacting sediments are related to interparticle water, surface adsorbed water and water resulting from exothermic chemical reactions by which they crystallise.

Without mobilisation and formation of accretions trace metal species are not concentrated.

Where significant volumes of sediment have been liquefied, desorption due to spontaneous synerectic shrinkage releases exceedingly small particles of trace metal sulphides and oxides to form veins and accumulate as mineral deposits.

Repeated mobilisation results in granite formation with higher temperatures from the exothermic chemical reactions by which the high-energy particulate matter (hydrolysed clay, polymeric silica, etc.) crystallises.

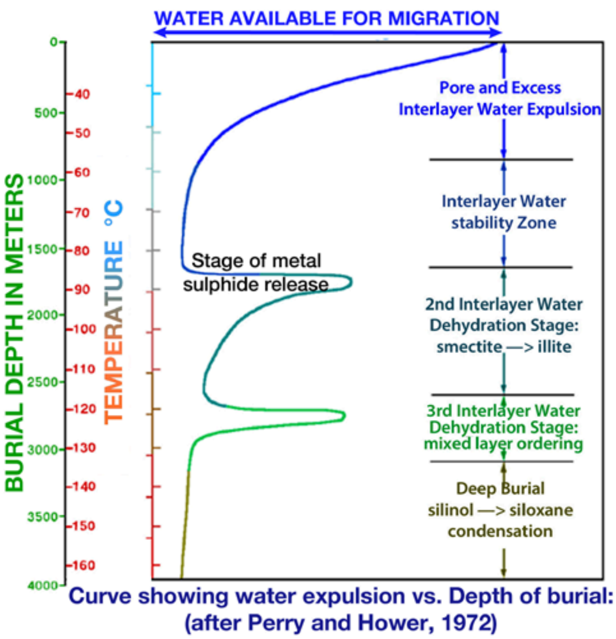


Figure 76: Some 3 tons of water must seep out of sediments for every ton of rock formed by their long slow compaction and crystallisation (Ref. 16).

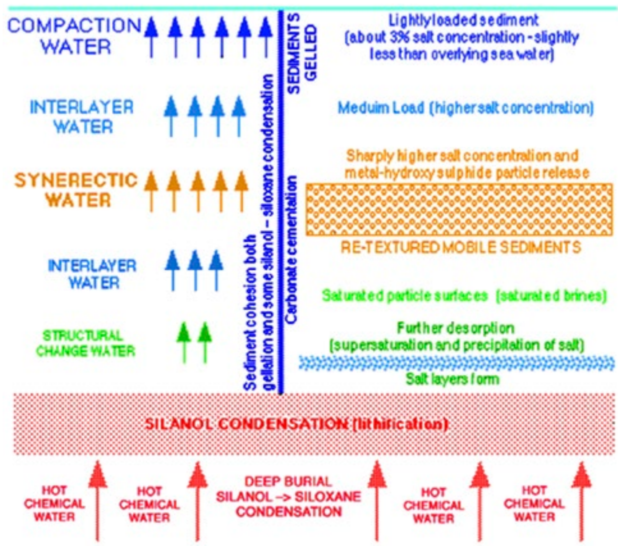


Figure 77. Sediment mobility and porphyroid formation increases adsorbed water release and leads to repeated mobilisation and granite formation.

General Diagram Representing Orebody Formation from Porphyroidal Source Rocks into Overlying Sediment Layers

Figure 78 is a diagram to represent a general sediment "plumbing system" whereby the trace metal hydrated sulphide particles are released from the condensing

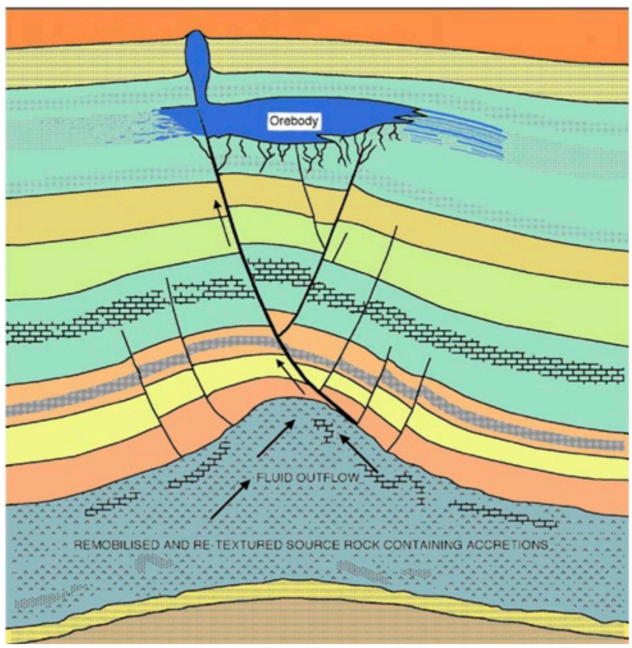


Figure 78. Diagram to indicate possible seepage paths for ore forming fluids from underlying source rocks.

accretions in re-textured source rock to flow out with the warm brines into favourable structures or host horizons.

Exceedingly small critical clusters of trace metal sulphides can pass through the finest openings to "sneak through the cracks" and form the various types of mineral deposits. They are metastable in suspension and the precipitated sulphides attract more particles to surfaces. Colloidal particles dispersed in the pore fluids are coagulated at the interface between fluid dispersion and gelatinous precipitate (particles linked to each other by satisfaction of surface charges). The gelatinous aggregate of successive layers of precipitate (colloform or concretionary texture) becomes synerectic.

Synerectic shrinkage exudes electrolyte from the accumulated layers to the interface. Continued precipitation creates a diffusion gradient by which the successive layers of the ore mineral precursors are built up.

Earlier and more diffuse upward seepage gives rise to stratiform deposits, but bedded, massive, disseminated, vein associated, and re-mobilised ores all have a similar genesis.

ACKNOWLEDGEMENTS

Permission from Connor Court Publications Pty Ltd to publish this summary and to include extracts and figures from the book is gratefully acknowledged. The first eight pages of this paper contain photographs of outstanding scientists and leaders of the successful Geopeko Limited mineral exploration team. Permission from those still living to publish their photographs is also gratefully acknowledged. The author is appreciative and thankful for AusIndustry monitoring of this research since 1984 and for the thorough scrutiny and analysis that certified compliance with the scientific method in 2006.

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REVOLUTIONARY NEW PUBLICATION

This outstanding publication is the result of inspired new fundamental research done in the field and in the laboratory by the author and a world leader in colloid science. Systematic use of the scientific method has established a new and complete understanding of how rocks and mineral deposits are formed.

The application of this understanding resulted in the discovery in Australia of 9 new mines containing 33 orebodies in a 15-year period. An independently commissioned consultants report (McKinsey & Company, Inc New York, 1975) demonstrated this dramatic improvement (+300%) in cost effectiveness of the mineral exploration programs when this revolutionary new understanding of ore forming processes was applied.

Teachers of geology and exploration geologists can now benefit from these new concepts. All involved need to understand the changes so that the principles established by this research can be adopted. This significant development and the new knowledge are paramount to advancing the Earth sciences.

In 1998 a research team at the Particulate Fluid Processing Centre at the University of Melbourne led by Professor T. W. Healy measured the forces between colloidal particles with an adapted atomic force microscope. This has confirmed the new fundamental understanding of the behaviour of surface charged sediment particles. It substantiates the research of John Elliston and his team of exploration geologists and their advisors.

This project is proudly supported by

AUSTRALIA

An Australian Government Initiative

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“We are blinded by what we think we know; disbelieve (your present convictions) *if you can.”*

The late Professor Samuel Warren Carey, 1911 - 2002, University of Tasmania.

BASIS OF THE RESEARCH

There is nothing more fundamental to our understanding of the way that rocks and orebodies were formed than the physical and chemical properties of the materials from which they were derived. This research has assumed that the properties of ancient sediments before lithification had the same properties that have now been confirmed by experiment and observations relating to natural basin sediments as we find them today. This has not been questioned and the conclusion that ancient sediment accumulations did have the same rheological and colloidal properties as the massive high-energy particle systems of today is simple and logical.

Oceanographic surveys, oil drilling, and the data from recent seismic reflection profiles have identified the turbidity current deposits, large-scale continental shelf failures, and massive updoming and diapirs in the shelf deposits and sedimentary basins of today. The geological record shows there were similar mass flow units and updomings in the older sediments that are now rocks.

Ancient sediments must have been hydrolysed and also contained the same extraordinarily large internal surface areas as those of today. Details of the structures and textures preserved in the rocks clearly show that the rheology and behaviour of the charged particles in ancient sedimentary components was in accord with the principles now established in colloid science.

This book illustrates these details. It simply points out that geologists with some knowledge of colloid and surface chemistry can identify inorganic structures and textures preserved in rocks derived directly or by diagenetic processes from ancient sedimentary materials. Geologists with some knowledge of biology are able to identify organic fossils preserved in ancient sediments in the same way. We are now also able to understand the inorganic textures and structures.

Formations and rock types from which dispersed ore minerals were concentrated to form orebodies can now be distinguished from those in which the trace metals remain dispersed. The shape, size, continuity and grade of different mineral deposits is much easier to assess if the ore forming processes are understood.

"If you get the basics right the rest will follow!"

Professor Barry Ninham,
Australian National University

THE RESEARCH ACHIEVEMENT

Geological processes by which mineral deposits are formed have been revealed by a series of industrial research projects based on work confirmed by recent achievements of an Australian Commonwealth Special Research Centre. The research has been applied by geologists to the extent that one of the major mining groups involved recorded one of the most successful periods of mine finding in Australia's history. The work has been extended to establish that the basic principles are relevant to all geological environments and mineral deposits generally. More effective development of mineral resources is of national importance. The confidential aspects of the research no longer apply and the new findings are now published and generally available.

The research introduces an exciting new alternative to traditional thinking in the Earth Sciences. It confirms that natural fine-grained particle systems behave in accordance with principles established in colloid and surface chemistry. This must therefore include diagenetic processes in ancient and modern natural sediment accumulations.

Liquefaction or shear in pasty flow of wet sediment pastes allows colloidal particles in natural sediments to re-arrange themselves into aggregates so that surface energy is reduced. These denser particle clusters are synerectic and subsequently liberate colloidal ore metal sulphide suspensions into brines as they condense. Rock masses are heated by chemical dehydration reactions as the particle aggregates finally crystallise.

This significant development and the new knowledge are paramount to advancing the Earth sciences.

J. N. Elliston, AM

OVERVIEW

T. W. Healy, AO

The scientific method seeks to explain natural phenomena using natural laws, verifiable and reproducible observations and measurements that validate logical conclusions.

Two outstandingly successful Australian research projects based on correct use of the scientific method have resulted in this interdisciplinary research that introduces significant new knowledge. The application of colloid science in this book has embraced the geological sciences in a coherent and compelling way.

In 1998 Professor T. W. Healy led a team of Particulate Fluids Processing Centre researchers at the University of Melbourne. They were successful in adapting an atomic force microscope to measure forces between colloidal particles due to their surface charge.

This substantiates the research of John Elliston's team of exploration geologists and their advisors. From the 1960's they have claimed that natural sediments are immense accumulations of high-energy particles containing colloids (particles 1 to 1,500 nanometers in size). When they are mobilised by earthquake shocks for example, these can achieve a more stable condition by aggregating to close-packed clusters. Heat is generated by chemical reactions when the particle clusters finally crystallise to metamorphic, porphyroidal or granitic rocks.

This fundamental research now resolves many long standing problems in the Earth sciences. The new understanding of the formation of mineral deposits has demonstrated much more efficient and cost effective mineral exploration. Application of these two innovative research achievements will certainly benefit economic development.

Carey, 1996, p.26 recognised this new knowledge, "years of intensive world-wide study of porphyroids, orbicules, and rapakivi granites demonstrated how these developed through colloidal processes". This new geological theory "has the same importance to that subject as Darwin's to biology" (Ninham and Nostro, 2010, p. 72).

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