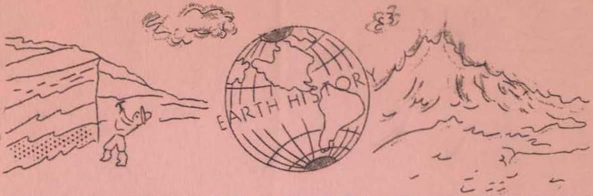

THE MINNESOTA GEOLOGIST

OFFICIAL BULLETIN

OF

THE GEOLOGICAL SOCIETY OF MINNESOTA

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THIRD ANNIVERSARY ISSUE

GEOLOGICAL SOCIETY OF MINNESOTA

831 SECOND AVENUE SOUTH
MINNEAPOLIS 2, MINNESOTA

The Society is devoted to the study of GEOLOGY and MINERALOGY for their cultural value.

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MEETINGS: October to May inclusive, 7:30 P.M. every Monday, not a holiday, large auditorium, 4th floor, Public Library, Hennepin Avenue and 10th Street, Minneapolis, Minnesota.

FIELD TRIPS: June until September inclusive. Visitors are very welcome, always.

ANNUAL DUES: Residents of Hennepin and Ramsey Counties $3.00 plus $1.00 additional for husband, wife, or dependant family members; for students and non-residents, $1.00.

Affiliated with
MID WEST FEDERATION OF GEOLOGICAL SOCIETIES

FIELD TRIP TO THE BLACK HILLS: Past President Charles H. Preston has taken to heart the duties of his new job--LEADER OF FIELD TRIPS EXTRAORDINARY. He has a way of "sticking his neck out", so he says, but he also has the habit of keeping possession of it and putting the job over. Anyway, he has graciously volunteered to lead another super field trip to the Bad Lands and Black Hills of South Dakota. The Bad Lands of South Dakota are, alone, very much worth while. Then, there is quite as much geologic interest in the Black Hills as in the Grand Canyon area and certainly greater variety. Your editor has just returned from a business trip to the Black Hills and while there made tentative arrangements for panning a little gold next summer. The trip is scheduled for the last week in June. Mr. Preston has already begun preparations so we should begin ours too.

DINNER MEETING: Several have suggested that we have another dinner meeting some time before the end of the lecture season, that it be held to a simple program including dinner, the usual lecture, an auction, and allow time for visiting. Please let us know what you think about it.

DR. D. B. LAWRENCE, who gave us such a splendid lecture on Paricutin at the Federation Banquet, returned to the Society the Honorarium we tendered to him with the suggestion that we purchase two books for the use of our members. These books are "Crater Lake: The Study of its Origin" and "Volcanoes Declare War". They have been ordered. We are most grateful to Dr. Lawrence for his extreme kindness, and we can assure him that he has made a lasting friend of every member of this organization. The directors have made Dr. Lawrence an Honorary Member.

JAPS-OLSON COMPANY, FRANK BEDOR VICE-PRESIDENT, Printing and Stationery, have contributed the paper for the covers of our Bulletin for one year. We are greatly indebted to them for their generosity, and we all do appreciate it very much.

AMERICAN MUSEUM OF NATURAL HISTORY OF NEW YORK CITY has given us a copy of Dr. Charles P. Berkey's book on the Geology of China. Perhaps not all of you know that Dr. Berkey worked out the geology of the Taylors Falls Quadrangle for his doctor's thesis at Minnesota. Later he became head of the Department of Geology at Columbia University and was geologist with the Roy Chapman Andrews famous expedition to the Gobi Desert in Asia. In exchange we are giving the American Museum of Natural History a complete set of our Bulletins. We are greatly indebted to the Museum and sincerely appreciate their kindness. Dr. Berkey is a member of our Society.

THIRD ANNIVERSARY: We are now three years old, and this is our Anniversary Issue. If we can improve as much in the next three years as we think we have, and as some of you have said we have, in the past three, we should have a fairly good Bulletin.

DATA SHEETS: Included in this issue are three data sheets contributed by Professor George M. Schwartz. They are authoritative and excellent for ready reference. Professor Lingren is possibly the greatest economic geologist of all time and anything he writes commands attention. Bateman's Classification is equally authoritative but is on different lines. Dr. Schwartz's "Important Minerals of Economic Deposits" should be kept handy for immediate reference when you are studying mines or ore deposits. They are well worth preserving, and we include them for that purpose.

TRUST FUND: A committee consisting of Past Presidents Preston, Syme, and Zalusky are working with the Directors on a plan to set up a trust fund for the Society. It is planned to establish a trust to be managed by three trustees to receive, hold and manage property and money for the benefit of the Society and its work. Details will be given in due time.

EDITOR'S NOTE

The Whaley-Eaton Service is one of the leading weekly letter services to business men published in Washington, D. C. Under date of September 28, 1946, they included in with their weekly letter a supplement on the "Future of Fission". We have secured special permission from them to present this article to you on this timely subject. We know you will be interested in reading it. We extend our appreciation to the Whaley-Eaton Service for their courtesy.

FUTURE OF FISSION

The Atom as a Source of Power

THE MINDS of thoughtful men, overwhelmed by the destructive possibilities of the atom, of bacteria and of the virus, increasingly turn toward the potential benefits which the New Knowledge could bring to Mankind. The comtemplation of a future in which the incredible results of his creative thinking are used by Man for his own destruction is altogether too painful. With the key to the fundamental power of Nature in his hands, it has to be assumed that Man will use it for the general benefit; that Western civilization will long enough survive for the New Utopia to be realized; that Man will come to know himself as well as he now knows the physical universe.

For the future could well be the millennium toward which humanity has groped for centuries. On the one hand, the dangers of the present are so obvious, the potential calamity so appalling, that the constructive mind, for the moment, is paralyzed. But on the other, the prospect is so bright, the contemplation of mankind released from poverty and its consequences so appealing, that it is salutary to turn from the possible Tragedy to the no less possible Promise of the New Era.

Operation Crossroads has been discontinued--as an experiment to determine how much of his handiwork Man can destroy in a fraction of a second. But in the larger sense, the Operation continues. "It is we who are at the crossroads, and the decision is whether mankind shall become obsolete", said an eminent scientist recently. The purpose of the present study is to show what, if Man survives, he may achieve as a result of his new command over Nature.

The recent report to the Atomic Energy Commission sets out the facts which govern the use of the atom as a source of power. It makes clear the fact that atomic power is far closer at hand than has hitherto been suspected. There are certain technical problems yet to be overcome; but by comparison with those already solved in the production of the atomic bomb these are trifling. The report shows beyond a doubt that power from the atom will be available shortly. Problems at the technical level have never in its history held up the progress of engineering, and only the most pessimistic can see them doing so now.

An astounding feature of this account is the cost comparison, for electricity generation, between a coal and an atomic plant--between, that is to say, a coal plant perfected and cheapened as to initial cost and as to cost of operation by a hundred years' experience--and the very first atomic plant. Even so, the original plant cost is estimated to be only two-and-a-half times greater for the atom than for coal. The cost of power so generated (including interest charges on the investment at 3% in each case) is even more nearly similar; 0.65¢ per kilowatt-hour for coal, 0.8¢ for the atomic source. It requires little imagination to see that, within a few years--particularly with coal costs mounting, as seems likely--"coal" power will far exceed atomic in cost.

The major cost of power to the consumer, in any event, is in its transmission to him, not in its generation. It is for this reason that hydraulic power differs so little in cost from that made from coal. It is here that the atom will most significantly revolutionize the power-world. The atomic plant can be brought near to the consumer; it need be located neither on a river nor near a coal-source. Nor does the argument that coal-fired plants are presently located in big cities influence the matter. If the plant is located within the city, the coal must be transported to it--if the plant is located on the river (or near the mine) the power must be wired to the consumer.

The atomic plant, requiring exceedingly little fuel by bulk, may operate for months on the fuel with which it is originally supplied. The "pipe-line", be it a string of coal-cars or a high-voltage transmission line, virtually disappears.

The foregoing applies to the nuclear power plant in locations already supplied with power from conventional sources. It is abundantly clear that, in due time, the atomic plant will offer serious competition to its present alternatives; this although all technical problems connected with the use of the atom as a power source are admittedly as yet unsolved. The controversy which has arisen, in both the technical and non-technical press, over the feasibility of nuclear power generation should not be allowed to obscure the picture--the facts already known, in the opinion of a vast majority of competent authorities, leave no room for any alternative interpretation than that given above.

Atomic power will be generated, it will be generated soon, and it will be generated at a competitive price.

Other supplies fail--the atom is the fundamental constituent of the universe, hence unfailing. What the Sun does the Atom can do. Where there is matter, there is now energy; no longer merely potential energy, but energy available to release humanity from unproductive toil. In tapping the fundamental reservoir of energy in Nature, in acquiring this instrument of the Creator of the Universe, Mankind is for the first time in history in a position to abolish poverty, to do anything mechanical energy permits, to revolutionize every human task from agriculture to medicine. Only one question remains--can Man control himself?

The foregoing is not an overstatement. By comparison with this last achievement, all human invention is insignificant--the wheel, the printing press, the steam engine, the airplane, all are trifles. Our discovery that matter is energy has delivered into our hands the key to the door of Heaven on Earth.

So vast is the revolution now called for in our thinking that few who have so far written on the Atomic Age have shown a fraction of the imagination for which the possibilities call. Many, it is true, have forecast sweeping benefits; the few who have seen nothing but problems are much less than convincing.

Nevertheless, to the lay reader, the existence of an alternative opinion--the "it-can't-be-done" school-- is disquieting and requires explanation. In the course of technical history it is over and over again apparent that each of man's discoveries is greeted by a semi-professional chorus of unimaginative detractors. As each new vista opens to the informed and unbiased mind, the prospect is clouded by pessimistic and so-called "conservative" interpretations.

Nor are the scientists themselves unguilty; their training, in the observation of facts and suitable deduction therefrom, leaves no room for imagination of the type required to forsee the social and other consequences of their own discoveries. A story, probably apocryphal, illustrates the point: it is said that Lord Kelvin, when demonstrating his first refrigerating machine, did so apologetically--this was a mere gadget, a neat technical trick, of no conceivable application or real consequence. Whether true or not, the story is at least illuminating.

The mind trained in non-imagination cannot be expected to utilize a neglected faculty on the spur of the moment.

The pessimists notwithstanding, it is certain that nuclear power will revolutionize the world far more completely than did the steam engine which heralded the Industrial Revolution. Even the most fertile imagination has always fallen short of the full magnitude of the consequence of man's knowledge; the less-than-most-imaginative prophets now appear merely foolish. The complete and final impossibility of communication by radio was "proved" less than fifty years ago!

The fraction of the earth's surface at present supplied with power is remarkably small. It has been argued that the amount of power available to each inhabitant of a country is a measure of the standard of life which it offers. Such an interpretation is, clearly, approximately correct. Non-industrialized China must depend on human muscle, on beasts of burden, on the wind for the propulsion of sailboats--the total available horsepower is but little greater than that inherent in the capacity for physical work of the inhabitants.

At the opposite end of the scale, the United States, with a total (including power plants, railroads, trucks, buses, automobiles, etc., etc.) of no less than 2.64 billion horsepower, offers the use of nearly 20 horsepower to each and every inhabitant, and this exclusive of his own physical work. Standard of life may be measured --in part-- by the power at one's command.

From this argument--as indeed from more direct reasoning--it is apparent that the undeveloped sections of the world must so remain until manpower can be supplemented by mechanical horsepower. The vast areas of China, of Brazil and of India, to name but three, at present support only an undernourished and sparse population. In each, conventional sources of power--oil, water or coal--are either unavailable or unexploited. Without industry, the standards of life are wretched, those of agriculture pathetic; even fertilizer production requires power. To such areas, the nuclear power plant offers an escape from Nature's parsimony. They are no longer at an insurmountable disadvantage by comparison with the more fortunate countries such as the U. S., where, in abundance, all three forms of power are richly available. With the introduction of readily available energy, the human inhabitants of the "powerless" areas can commence their ascent of the ladder of civilization. Certainly it will be long before they reach the heights now achieved elsewhere--but the long ascent of progress is now theirs to make; the power inherent in matter is available to all, irrespective of location or fortune.

What has been said above applies to the release of atomic power by the method at present understood--by nuclear fission. It applies exclusively to the generation of power in large-scale, stationary plants. For this limitation, there exist at the present time good technical reasons. The process of fission of heavy elements produces, in addition to energy and useful end-products, powerful radiations lethal to human beings. To prevent their escape, the nuclear "pile" is surrounded by heavy shielding, as a result of which it cannot be expected that a practicable plant can be made--on present knowledge--to weigh less than 100 tons. Such a weight, most plainly, renders the present device utterly unsuitable for the airplane, truck or automobile, just practicable for the largest locomotive, clearly possible for large seagoing vessels.

The conclusion that smaller plants are not at present foreseen, however, does not compel the supposition that they will not appear in time, as many have argued. The very reverse is true. Already on the horizon are entirely new methods of releasing the energy in matter.

Among these are new methods of deriving power by the fission of heavy elements, unaccompanied by lethal radiation products in their present quantity. Energy can be derived also, by processes other than fission. The fusion of light elements (the opposite process to the fission of heavy ones) is also accompanied by a vast release of energy--it is amazing to speculate on the possibilities of a plant operating by the fusion of so light, and so very cheap, an element as hydrogen. By all these as yet unexplored systems, entirely new possibilities as to weight and size are opened up. Thereby, atomic fuel could replace that now used even in the smallest and lightest power plants.

We must note, parenthetically, that the extensive benefits which nuclear energy can offer the world will be realized only if, in the first instance at least, comprehensive research plans are carried forward in the United States. There is no monopoly on scientific knowledge--it is certain that any technically progressive nation could, on the basis of such knowledge as is freely available to all, construct and operate an atomic pile. For the less industrialized nations, this would, true, present a formidable problem, but not an insoluble one.

The production of power from a nuclear source would not be feasible, on the other hand, for any country other than the U. S. for many years' time.

It therefore behooves the U. S., both on grounds of security and of common humanity, to prosecute this research with all possible speed, and to ensure that the utmost freedom from unnecessary governmental interference is secured. The Government, plainly, must have a monopoly on all fissionable materials; but it must have no such monopoly in the general development of nuclear industry.

"The Government," writes Dr. Wheeler, "is not an engineering concern. Every dollar spent by the Government in encouraging industry to enter this new field will be worth ten dollars spent by the Government's trying to do it itself." Properly to exploit this great discovery, atomic legislation must give to industry the greatest possible freedom compatible with national (and international) security.

It is over-optimistic to hope that political folly, indeed human stupidity in general, will not delay the realization of all the benefits which the new knowledge can bring about; but neither is it conceivable that the delay will be final. All that has been said here leads but to one conclusion--Man is at the threshold of a new era in his age-long battle to control his environment.

The possibilities are so all-embracing that even the most fertile mind can at best only see ahead for a decade. Yet one clear result may be forecast--the provision of power to those areas and those human beings now deprived of its benefits, and correspondingly free of its responsibilities, will profoundly change the social, political and economic face of the world. The utmost of human wisdom will be required to avoid the utmost of human misery as a consequence; but, for Man, should he live to see it, the New Era should dawn brightly, indeed.

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BULLETIN BOARD — ECONOMIC GEOLOGY

The object of Dr. Swartz's lectures given prior to January 1st, was to give us a general knowledge of the minerals constituting ore deposits. Beginning with the lecture on January 6th, each lecture will be devoted to a description of the principal ore bodies of the world and their economic importance. You will find this information a very great help to you in your general reading, in more ways than one. Wars are fought, peace is made, and nations die or are born depending oftentimes on the ore deposits they control. This series is just starting. Bring your friends.

VIII	JANUARY 13, 1947:	COPPER DEPOSITS
IX	JANUARY 20:	GOLD AND SILVER DEPOSITS
X	JANUARY 27:	LEAD AND ZINC DEPOSITS
XI	FEBRUARY 3:	DEPOSITS OF ALUMINUM, TIN AND NICKEL, etc.
XII	FEBRUARY 10:	COAL DEPOSITS: ORIGIN: Geologic Distribution
XIII	FEBRUARY 17:	COAL DEPOSITS: Geographic Distribution-Significance
XIV	FEBRUARY 24:	SALT DEPOSITS: (The Salines)
XV	MARCH 3:	CLAY DEPOSITS AND CLAY PRODUCTS
XVI	MARCH 10:	DEPOSITS OF PHOSPHOROUS, GRAPHITE, SULPHUR, ASBESTOS, AND LESSER NON-METALLICS.

IMPORTANT MINERALS OF ECONOMIC DEPOSITS — DATA SHEET

A. MAGMATIC SEGREGATIONS

Feldspars	$(KAlSi_3O_8$ $(NaAlSi_3O_8$ $(CaAl_2Si_2O_4$	Rutile	TiO_2	Pyrite	FeS_2
		Spinel	$MgAl_2O_4$	Chalcopyrite	$CuFeS_2$
Micas	Complex	Magnetite	Fe_3O_4	Chromite	$FeCrO_4$
Pyroxenes	$RSiO_3$*	Ilmenite	$FeTiO_2$	Corundum	Al_2O_3
Amphiboles	$RSiO_3$*	Pyrrhotite	FeS+Sn	Diamond	C
Olivine	$(Mg,Fe)_2SiO_4$	Pentlandite	(Fe,Ni)S	Feldspathoids-	
Apatite	$(CaF)Ca_4(PO_4)_3$			Nephelite	$K_2Na_6Al_8Si_9O_{34}$

*R=Ca,Mg,Fe also Mn,Na_2, K_2, H_2

B. PEGMATITES

Feldspar	See above	Columbite-		Fluorite	CaF_2
Quartz	SiO_2	Tantalite	$FeNb_2O_6.FeTa_2O_6$	Spinel	$MgAl_2O_4$
Micas	Complex	Garnet	$R_3R_2(SiO_4)_3$	Spodumene	$LiAl(SiO_3)_2$
Apatite	$(CaF)Ca_4(PO_4)_3$	Pyrrhotite	FeS+Sn	Titanite	$CaTiO_2$
Beryl	$Be_3Al_2(SiO_3)_6$	Rutile	TiO_2	Tourmaline	$H_9Al_3(B.OH)_2Si_4O_{19}$
Cassiterite	SnO_2	Scheelite	$CaWO_4$	Wolframite	$(Fe,Mn)WO_4$
Amblygonite	$Li(AlF)PO_4$	Molybdenite	MoS_2	Triphylite	$Li(Fe,Mn)PO_4$
		Topaz	$Al(F,OH)_2AlSiO_4$		

C. PYROMETASOMATIC OR CONTACT METAMORPHIC DEPOSITS

Characteristic are silicates of calcium.

GANGUE:

Quartz	SiO_2	Mica	Complex	Epidote	$HCa_2(Al,Fe)_3Si_3O_{13}$
Feldspar	See above	Calcite and		Ilvaite	$(CaFe_2(FeOH)(SiO_4)_2$
Amphiboles	See above	Carbonates		Scapolite	$Ca_4Al_6Si_6O_{25}$
Pyroxenes	See above	Chlorite	$H_8Mg_5Al_2Si_3O_{18}$	Sericite	$H_2KAl_3(SiO_4)_3$
Andalusite	Al_2SiO_5	Idocrase	[Ca (Al,OHF)]	Sillimanite	Al_2SiO_5
Garnet	$R_3,R_2(SiO_4)_3$	(Vesuvianite)	$Al_2(SiO_4)_5$	Spinel	$MgAl_2O_4$
Apatite	$(CaF)Ca_4(PO_4)_3$	Corundum	Al_2O_3	Staurolite	$HFeAl_5Si_2O_{13}$
				Wollastonite	$CaSiO_3$

ORE:

Arsenopyrite	FeAsS	Graphite	C	Pyrite	FeS_2
Chalcopyrite	$CuFeS_2$	Hematite	Fe_2O_3	Pyrrhotite	FeS+Sn
Cubanite	$CuFe_2S_4$	Magnetite	Fe_3O_4	Sphalerite	ZnS

D. HYPOTHERMAL DEPOSITS

Feldspars	See above	Sphalerite	ZnS	Graphite	C
Amphiboles	See above	Wolframite	$(Fe,Mn)WO_4$	Hematite	Fe_2O_3
Pyroxenes	See above	Scheelite	$CaWO_4$	Magnetite	Fe_3O_4
Garnets	See above	Pyrite	FeS_2	Molybdenite	MoS_2
Micas	See above	Pyrrhotite	FeS+Sn	Cassiterite	SnO_2
Chlorite	$H_8Mg_5Al_2Si_3O_{18}$	Tellurides		Rutile	TiO_2
Carbonates		Arsenopyrite	FeAsS	Topaz	$Al(F_2OH)_2Al,SiO_4$
Quartz		Chalcopyrite	$CuFeS_2$	Fluorite	CaF_2
Tourmaline	See above	Gold	Au		

E. MESOTHERMAL DEPOSITS

Carbonates	(several)	Arsenopyrite	$FeAsS$	Gold			
Barite	$BaSO_4$	Pyrite	FeS_2	Molybdenite	MoS_2		
Quartz	SiO_2	Bismuthinite	Bi_2S_3	Polybasite	$9Ag_2S.Sb_2S_3$		
Chlorite	$H_8Mg_5Al_2Si_3O_{18}$	Bornite	Cu_4FeS_5	Proustite	$3Ag_2S.As_2S_3$		
Sericite	$H_2KAl_3(SiO_4)_3$	Chalcocite	Cu_2S	Pyrargyrite	$3Ag_2S.Sb_2S_3$		
Fluorite	CaF_2	Chalcopyrite	$CuFeS_2$	Stibnite	Sb_2S_3		
Opal	$SiO_2.nH_2O$	Covellite	CuS	Tellurides			
Orthoclase	$KAlSi_3O_8$	Enargite	Cu_3AsS_4	Tetrahedrite	$4Cu_2S.Sb_2S_3$		
Argentite	Ag_2S	Galena	PbS	Sphalerite	ZnS		

F. EPITHERMAL DEPOSITS

Adularia	$KAlSi_3O_8$	Zeolites		Gold	Au
Alunite	$K_2Al_6(OH)_{12}(SO_4)_4$	Argentite	Ag_2S	Marcasite	FeS_2
Carbonates		Arsenopyrite	$FeAsS$	Polybasite	$9Ag_2S.Sb_2S_3$
Barite	$BaSO_4$	Bornite	Cu_4FeS_5	Proustite	$3Ag_2S.As_2S_3$
Celestite	$SnSO_4$	Tellurides		Pyrargyrite	$3Ag_2S.Sb_2S_3$
Chalcedony, opal,		Chalcopyrite	$CuFeS_2$	Pyrite	FeS_2
Chert, quartz,		Chalcocite	Cu_2S	Realgar	AsS
Chlorite	$H_8Mg_5Al_2Si_3O_{18}$	Cinnabar	HgS	Stibnite	Sb_2S_3
Kaolin	$H_4Al_2Si_2O_9$	Galena	PbS	Tetrahedrite	$4Cu_2S.Sb_2S_3$
Rhodochrosite	$MnCO_3$	Sphalerite	ZnS	Fluorite	CaF_2
Sericite	$H_2KAl_3(SiO_4)_3$			Stephanite	$5Ag_2S.Sb_2S_3$

G. DEPOSITS AT SHALLOW DEPTHS BY COLD METEORIC SOLUTIONS

Carbonates		Fluorite	Sphalerite	)
Sulphates		Gypsum	Pyrite	)
Calamine (= Hemimorphite)	H_2ZnSiO_5	Kaolin	Smithsonite	) See
Celestite	$SnSO_4$	Opal	Uranium minerals	) above
Chalcedony	SiO_2	Marcasite	Vanadium minerals	)
Chert	SiO_2	Galena	Barite	)
Anhydrite	$CaSO_4$			

H. SEDIMENTARY DEPOSITS

Quartz	SiO_2	Limonite	$Fe_2O_3.H_2O$	Halite	$NaCl$
Chert	SiO_2	Hematite	Fe_2O_3	Sylvite	KCl
Carbonates		Psilomelane		Many other chlorides,	
Clay minerals		Pyrolusite	MnO_2	nitrates	
Bauxite	$Al_2O_3 2H_2O$	Pyrite		sulphates,	
Opal	$SiO_2.nH_2O$	Gypsum	$CaSO_4 2H_2O$	borates in	
				deposits formed by evaporatior	

I. PLACER MINERALS

Gold		Garnet*	
Platinum		Cassiterite	SnO_2
Diamond		Rutile	TiO_2
Ilmenite	$FeTiO_2$	Monazite	Phosphate of cerium metals
Magnetite			

*Garnets $R^{II}_3R^{III}_2(SiO_4)_3$

R^{II}=Ca,Mg,Fe,Mn
R^{III}=Al,Fe,Cr,Ti

Grossularite= $Ca_3Al_2(SiO_4)_3$
Pyrope= $Mg_3Al_2(SiO_4)_3$
Almandite= $Fe_3Al_2(SiO_4)_3$
Spessartite= $Mn_3Al_2(SiO_4)_3$
Andradite= $Ca_3Fe_2(SiO_4)_3$

(Characteristic gangue minerals are underlined)

A CLASSIFICATION OF MINERAL DEPOSITS

(From "Mineral Deposits" by W. Lindgren)

I. Deposits produced by mechanical processes of concentration, temperature and pressure moderate.

II. Deposits produced by chemical processes of concentration, temperature and pressure vary between wide limits.

A. In bodies of surface waters
   1. By interaction of solutions
      a. Inorganic reactions
      b. Organic reactions
   2. By evaporation of solvents.
   — Temperature, 0° to 70° C. ±; Pressure, Moderate to strong

B. In bodies of rocks.
   1. By concentration of substances contained in the geologic body itself.
      a. Concentration by rock decay and residual weathering near surface — Temperature, 0°-100° C. ±; Pressure, moderate
      b. Concentration by ground water of deeper circulation. — Temperature, 0°-100° C. ±; Pressure, moderate
      c. Concentration by dynamic and regional metamorphism — Temp. up to 400° C. ±; Pressure, high
   2. Concentration effected by introduction of substances foreign to the rock.
      a. Origin independent of igneous activity.
         By circulating atmospheric waters at moderate or slight depth. — Temperature, to 100° C. ±; Pressure, moderate
      b. Origin dependent upon the eruption of igneous rocks.
         (a) By hot ascending waters of uncertain origin, but charged with igneous emanations.
            (1) Deposition and concentration at slight depth. Epithermal deposits. — Temp. 50°-200° C. ±; Pressure, moderate.
            (2) Deposition and concentration at intermediate depths. Mesothermal deposits. — Temp. 200°-300° C. ±; Pressure, high.
            (3) Deposition and concentration at great depth or at high temperature and pressure. Hypothermal deposits. — Temp. 300°-500° C. ±; Pressure, very high.
         (b) By direct igneous emanations.
            (1) From intrusive bodies. Contact metamorphic or pyrometasomatic deposits. — Temp. probably 500°± - 800° C. ±; Pressure, very high.
            (2) From effusive bodies. Sublimates, fumaroles. — Temp. 100°-600° C.; Pressure, atmospheric to moderate.

C. In magmas, by processes of differentiation
   a. Magmatic deposits proper. — Temperature, 700°-1500° C. ±; Pressure, very high.
   b. Pegmatites — Temperature, about 575° C. ±; Pressure, very high

BATEMAN'S PROPOSED CLASSIFICATION

(Economic Mineral Deposits - Wiley & Co., 1942)

Process	Deposits	Examples
1. Magmatic Concentration	I. Early magmatic:	
	A. Disseminated crystallization	Diamond pipes
	B. Segregation	Chromite deposits
	C. Injection	Kiruna magnetite
	II. Late magmatic:	
	A. Residual liquid segregation	Taberg magnetite
	B. Residual liquid injection	Adirondack magnetite
	C. Immiscible liquid segregation	Insizwa sulphides
	D. Immiscible liquid injection	Sudbury sulphides?
2. Sublimation	Sublimates	Sulphur
3. Contact metamorphism	Contact metamorphic: Iron, copper, gold, etc.	Cornwall magnetite Morenci copper, etc.
4. Replacement	Replacement:	
	A. Massive	Bisbee copper
	B. Lode fissure	Kirkland Lake gold
	C. Disseminated	"Porphyry" coppers
5. Replacement-filling	Replacement-filling deposits	Butte copper veins
6. Cavity filling	Cavity filling (open space deposits):	
	A. Fissure veins	Pachuca, Mexico
	B. Shear-zone deposits	Otago, New Zealand
	C. Stockworks	Altenberg tin, Germany
	D. Ladder veins	Morning Star, Australia
	E. Saddle-reefs	Bendigo, Australia
	F. Tension-crack fillings (Pitches and flats)	Wisconsin Pb and Zn
	G. Breccia fillings:	
	1. Volcanic	Bassick pipe, Colorado
	2. Tectonic	Mascot, Tenn., Zn
	3. Collapse	Bisbee, Arizona
	H. Solution-cavity fillings	
	1. Caves and channels	Wisconsin-Illinois Pb and Zn
	2. Gash veins	Upper Mississippi Valley Pb and Zn
	I. Pore-space fillings	"Red bed" copper
	J. Vesicular fillings	Lake Superior Copper

BATEMAN'S PROPOSED CLASSIFICATION
(Continued)

Process	Deposits	Examples
7. Sedimentation (exclusive of evaporation)	Sedimentary: Iron, manganese, phosphate, etc.	Clinton iron ores
8. Evaporation	Evaporites:	
	A. Marine	Gypsum, salt, potash
	B. Lake	Sodium carbonate, borates
	C. Ground water	Chile Nitrates
9. Mechanical concentration	Placers:	
	A. Stream	California placers
	B. Beach	Nome, Alaska, gold
	C. Eluvial	Dutch East Indies tin
	D. Eolian	Australian gold
10. Residual concentration	Residual deposits: Iron, manganese, bauxite, etc.	Lake Superior iron ores Gold Coast manganese Arkansas bauxite
11. Surficial oxidation and supergene enrichment	Oxidized, supergene sulphide	Chuquicamata, Chile Ray, Ariz., copper
12. Metamorphism	A. Metamorphosed deposits	Rammelsberg, Germany
	B. Metamorphic deposits	Graphite, asbestos, talc, soapstone, sillimanite group, garnet

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