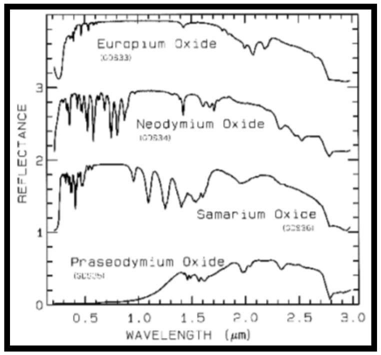
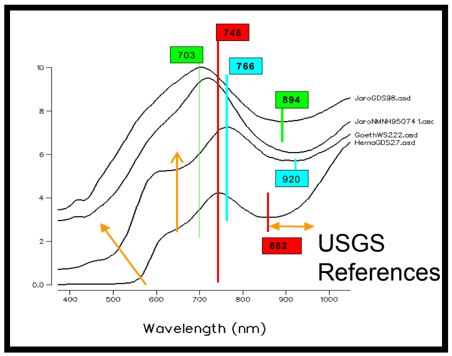
VIS-NIR-SWIR FIELD SPECTROSCOPY AS APPLIED TO PRECIOUS METALS EXPLORATION: GOLD SYSTEMS

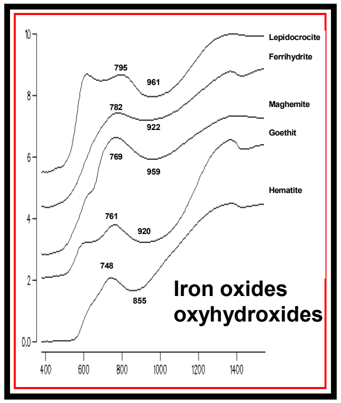
VISIBLE RANGE



– Plots of europium, neodymium oxide, samarium oxide, praseodymium oxide from the USGS reference library.

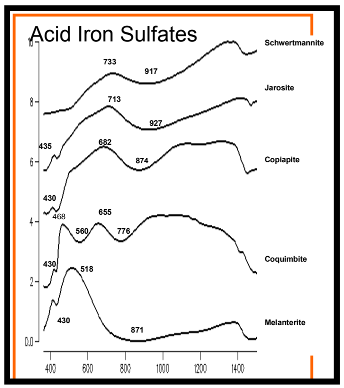


The three most common iron minerals encountered in Au and Cu deposits are jarosite, goethite and hematite. The plot shows spectral profiles and wavelengths for these minerals in the visible range, where most of their diagnostic features occur. The emission features are more consistent and reproducible then the absorption features. These features all have a range. These minerals are usually mixtures of each other.

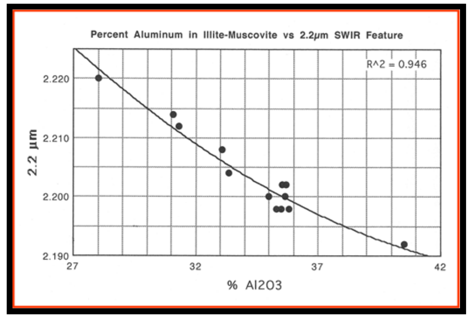


The more common iron oxides and hydroxides are lepidocrocite, ferrihydrite, maghemite. Goethite

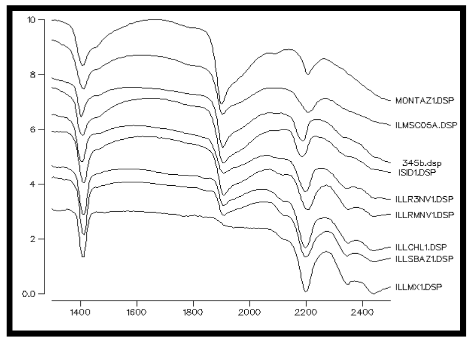
and hematite.



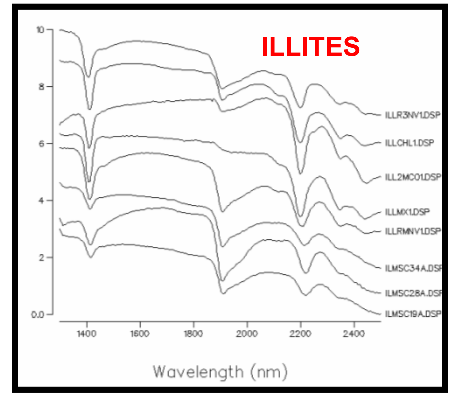
Iron sulfates are very useful to determine pH. They include Schwertmannite, jarosite, copiapite, coquimbite and melanterite



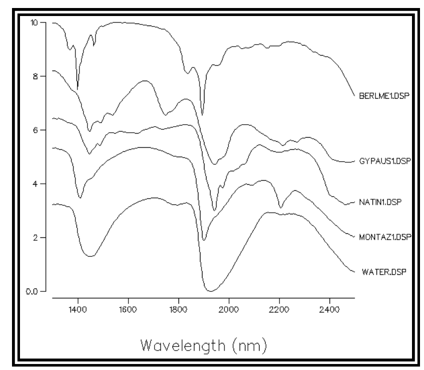
Aluminum content of illites can be estimated from the 2.2 μm absorption feature, which shifts relative to the percent aluminum present. There appears to be a deposit-specific correlation in that when illite/"sericite"/muscovite alteration is present, there are higher amounts of aluminum apparently associated with the ore zones. This also has been documented by Post and Noble (1993) and their data is plotted against spectral wavelength values collected from their published samples.



A very important series is the one from montmorillonite (A) through to muscovite [I]. This goes through mixed layer smectite/illite [B] and illite/smectite [C, D] to illite [E, F, G, H]. This is the most complicated series commonly worked with in alteration systems. Changes in water content, profile shape and wavelength are all subtle between the different species in the series



Feature positions for a cross section of muscovites and illites from SPECMIN™ range from 2198nm to 2212 nm, with the majority falling within 2200-2204 nm.
The illites plotted in Figure 9 are from different environments and from top to bottom are [A] Hog Ranch, Nevada, epithermal gold deposit; [B] Chuquicamata, Chile, porphyry copper; [C] Leadville, Colorado, gold vein system; [D] Cananea, Mexico, porphyry copper deposit; [E] Round Mountain, Nevada, disseminated gold deposit; [F, G, H] sedimentary illites from Illinois shales



Different water sites from channel water in beryl to molecular water in gypsum to zeolite channel water to interlayer water in smectite to surface water.

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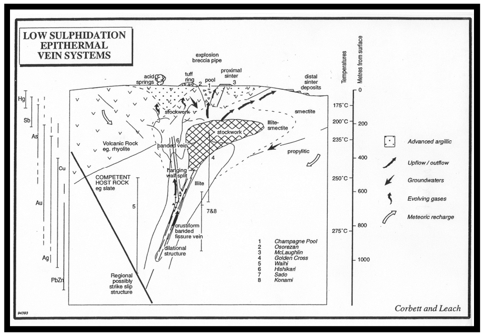
EPITHERMAL GOLD - LOW SULFIDATION



Model for a low-sulfidation epithermal gold system. Note distribution of alteration zoning and known deposits. (Corbett and Leach, 1998)

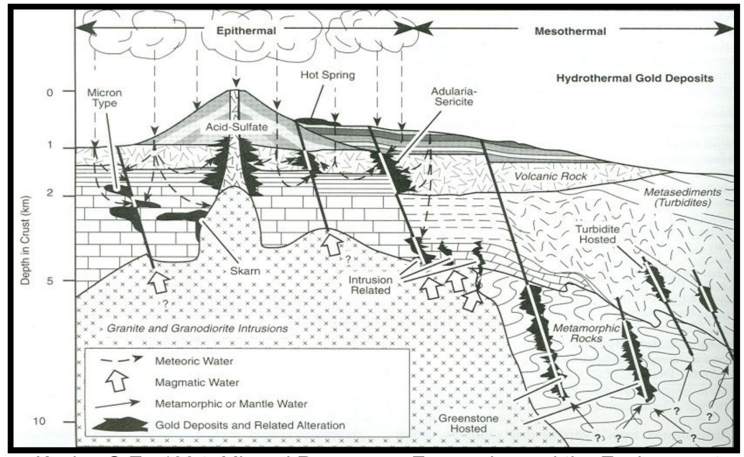
Major Global Deposits

EL PEÑON, Chile	MARTA, Peru
ESQUEL, Argentina	ROUND MOUNTAIN, Nv
CERRO VANGUARDIA, Argentina	COMSTOCK, Nv
HISHIKARI, Japan	SLEEPER, Nevada
GOSAWONG , Indonesia	MIDAS, Nevada
KUPOL, Russia	WAIHI , New Zealand
ROSIA MONTANA, Romania	GOLDEN CROSS, NZ
LIHIR, PNG	CERRO BAYO, Chile
TRES CRUCES, Peru	KORI KOLLO, Bolivia

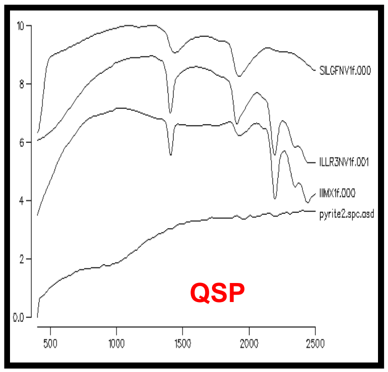
COMMON ALTERATION MINERALS- LSS

ILLITE KAOLINITE CHLORITES
ILLITE/SMECTITE BUDDINGTONITE EPIDOTE
Montmorillonite ADULARIA* ZEOLITES
QUARTZ CALCITE HEMATITE

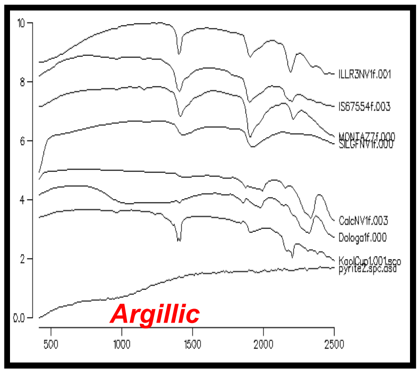
*Adularia is not infrared active.



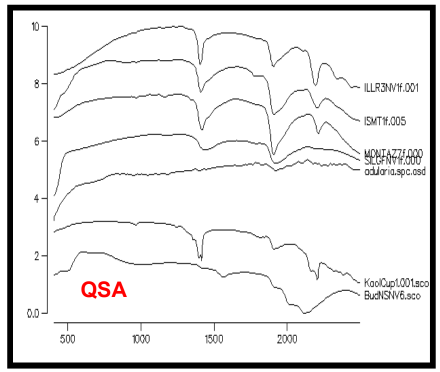
Kesler, S.E., 1994, Mineral Resources, Economics and the Environment : Macmillan, New York, 394 p



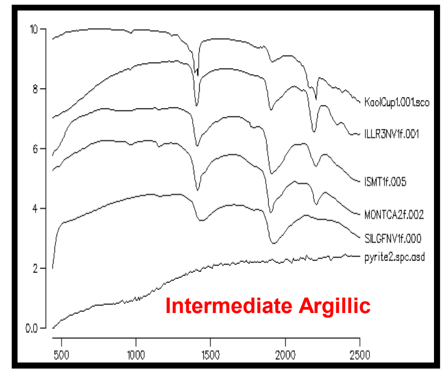
QSA alteration plot includes quartz, illite, muscovite, pyrite.



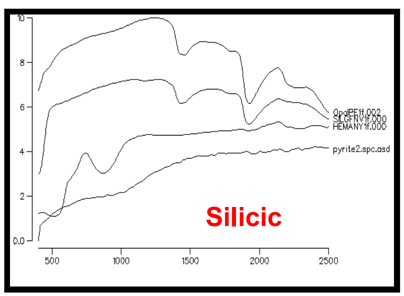
Illite, mixed layer illite/smectite, montmorillonite, quartz, calcite, dolomite, kaolinite and pyrite



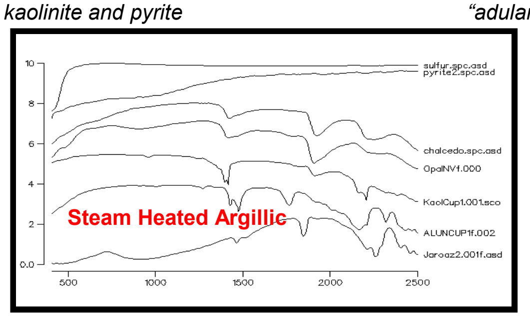
Minerals include illite, mixed layer illite/smectite, montmorillonite, quartz, "adularia",kaolinite and buddingtonite



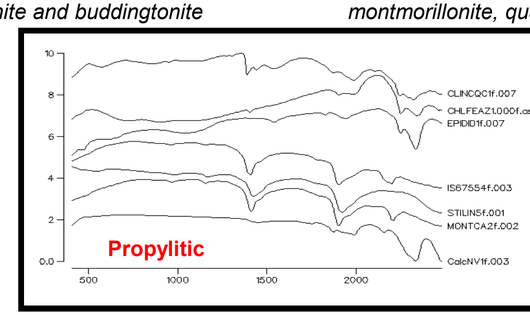
Intermediate Argillic Alteration shows kaolinite, illite, illite/smectite, montmorillonite, quartz, pyrite



Minerals include opal, chalcedony, quartz, hematite, and pyrite.



Minerals include sulfur, pyrite. Chalcedony, opal, kaolinite, alunite, jarosite



Minerals include: Mg-Chlorite, Fe-Chlorite, epidote, illite/smectite, zeolite. Montmorillonite and calcite

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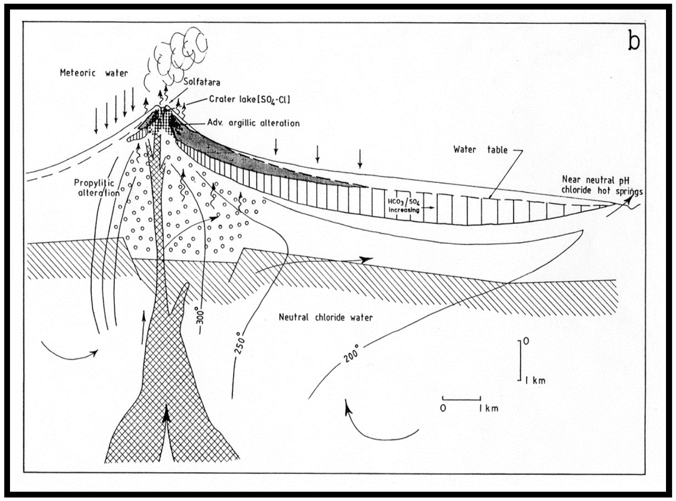
EPITHERMAL GOLD - HIGH SULFIDATION



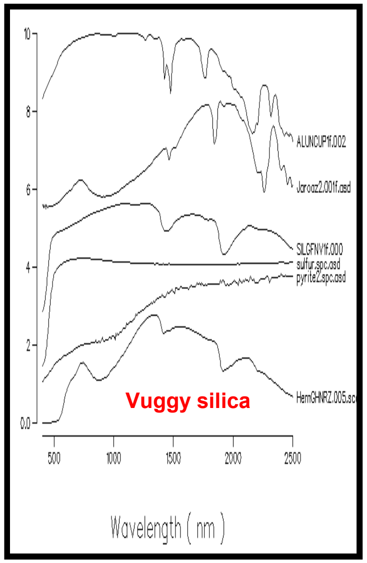
Model for High Sulfidation Gold System showing alteration zones and feeder structure. Source: Henley and Ellis, 1983

List of Well Known Deposits – Distribution

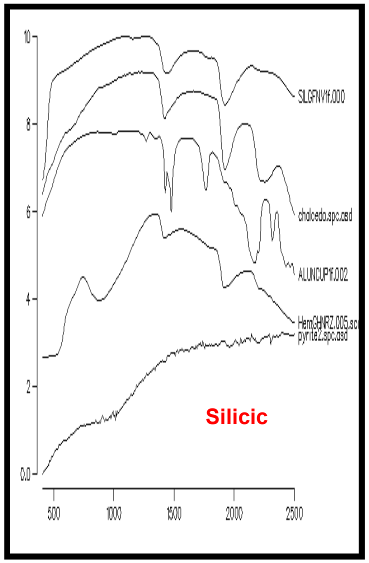
GOLDFIELD, NV	ZIJINSHAN, China
YANACOCHA, Peru	SIPAN, Peru
SUMMITVILLE, CO	TAMBO, Chile
LEPANTO, Phillipines	TANTAHUATAY, Peru
PASCUA-LLAMA, Chile-Argentina	AQUA RICA, Argentina
PIERINA, Peru	QUIMSACOCHA, Ecuador
PUEBLO VIEJO, Dominican Republic	MARTABEIndonesia
ALTA CHACAMA,Peru	VELADERO, Argentina
LA COIPA, Chile	RODIQUILAR, Spain
MULATOS, Mexico	FURTEI, Sardinia

COMMON ALTERATION MINERALS- HSS

ALUNITE • OPAL • DICKITE • PYROPHYLLITE • DIASPORE • ZUNYITE • TOPAZ • ILLITE • KAOLINITE • CHLORITES • ILLITE/SMECTITE • EPIDOTE • QUARTZ • MONTMORILLONITE GEOTHITE • JAROSITE • HEMATITE



Vuggy silica alteration includes alunite, jarosite, quartz, sulfur, pyrite, hematite



Minerals include quartz, chalcedondy, alunite, hematite, pyrite. Barite is not IR active.

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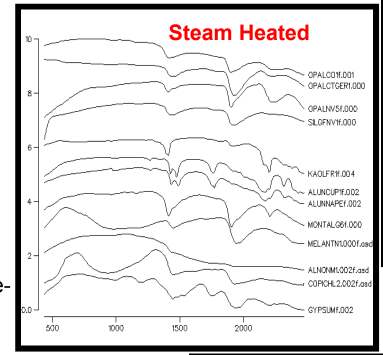
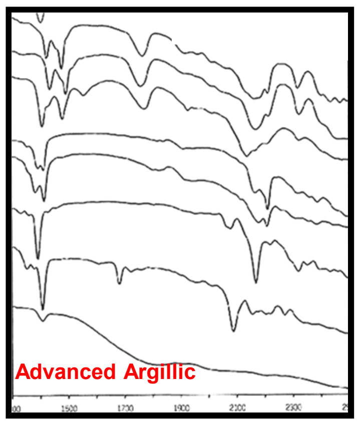
STEAM HEATED BLANKET

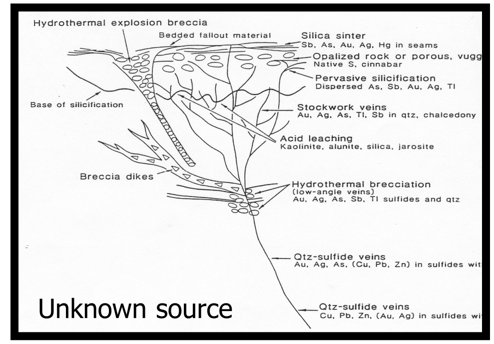
Opaline silica, Cristobalite
Microcrystalline quartz
Kaolinite, Alunite, Natroalunite
Montmorillonite, Melanterite
Sulfur, Alunogen, Copiapite, Gypsum, Fe-sulfates, Fe oxyhydroxides

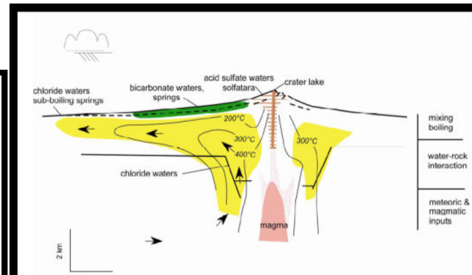




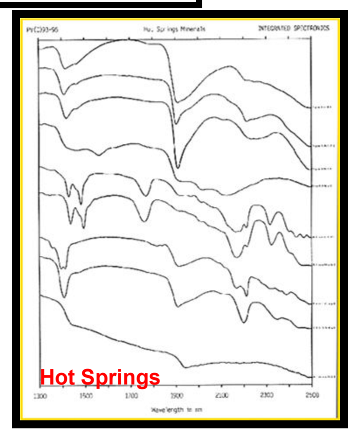
Alunite-K, Alunite-Na Zunyite Kaolinite Dickite Pyrophyllite, Topaz, Diaspore

HOT SPRINGS

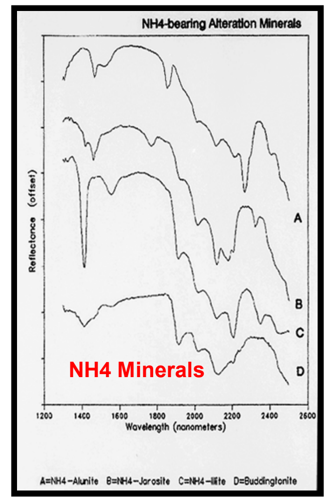




Source: Stuart Simmons, 2007

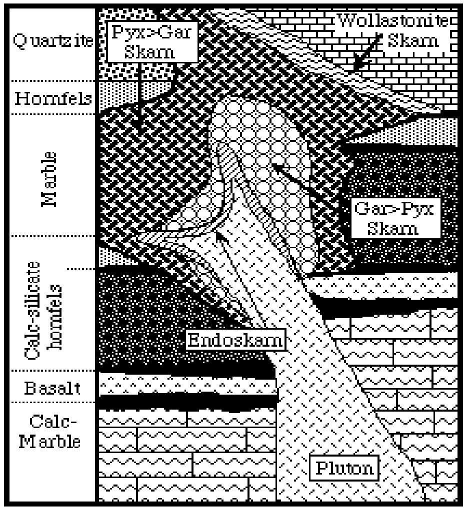


Minerals include: SILICA OPAL OPAL BUDDINGTONITE ALUNITE-K, ALUNITE-Na KAOLINITE ILLITE, COPIAPITE, Fe-Sulfates, Fe Hydroxides

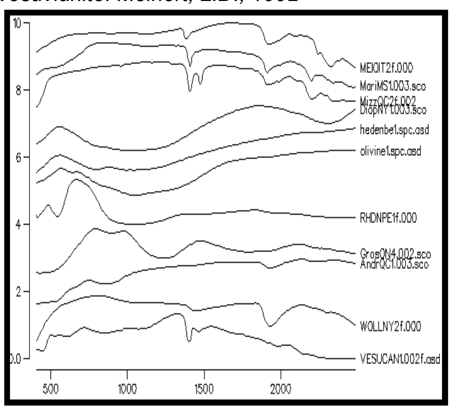


Minerals include: NH4-jarosite, NH4-alunite, NH4-illite, Buddingtonite

SKARNS



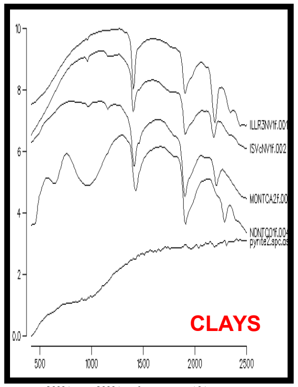
Zonation of most skarns reflects the geometry of the pluton contact and fluid flow. Such skarns are zoned from proximal endoskarn to proximal exoskarn, dominated by garnet. More distal skarn usually is more pyroxene-rich and the skarn front, especially in contact with marble, may be dominated by pyroxenoids or vesuvianite. Meinert, L.D., 1992



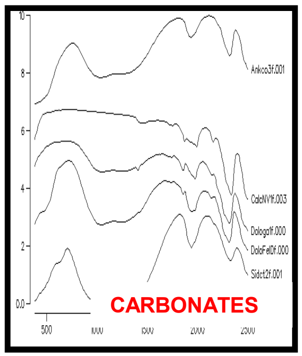
PROGRADE ALTERATION

Minerals include: Scapolite-meionite, scapolite-marialite, scapolite-mizzonite, diopside, hedenbergite, olivine, rhodonite, grossularite, andradite, wollastonite, and vesuvianite.

RETROGRADE

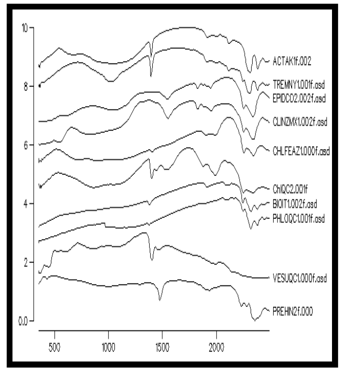


– Illite, Illite/smectite, montmorillonite, nontronite, and pyrite.

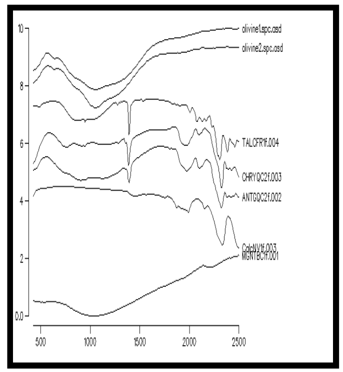


Minerals include Ankerite, calcite, dolomite, Fe-dolomite, siderite.

RETROGRADE



Actinolite, tremolite, epidote, clinozoisite, Fe-Chlorite, Mg-chlorite, biotite, phlogopite, vesuvianite, and prehnite



Minerals include forsterite, serpentine, talc, calcite, tremolite, magnetite

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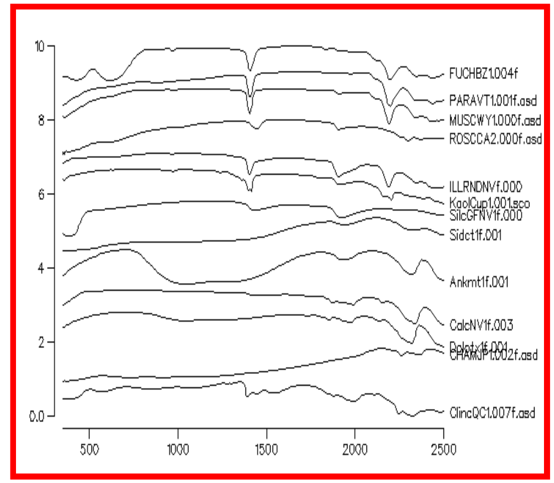
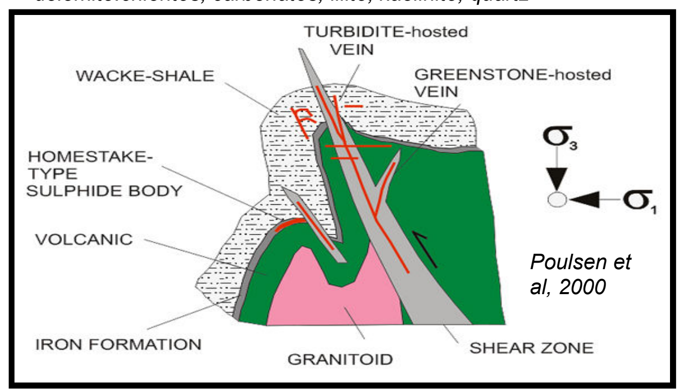
OROGENIC GOLD



Cr-muscovite, paragonite muscovite, roscoelite, illite, kaolinite, quartz, siderite, ankerite, calcite, dolomite.chlorites, carbonates, illite, kaolinite, quartz



Corbett, G.J., and Leach, T.M., 1998, Southwest Pacific rim gold-copper systems: Structure, alteration and mineralisation: Economic Geology, Special Publication 6, 238 p., Society of Economic Geologists.

Cox, D. P., and Singer, D. A., eds., 1986, Mineral deposit models: U.S. Geological Survey, Bulletin 1693, 379 p

Henley, R. W. and Ellis, A. J. (1983) Geothermal systems, ancient and modern: a geochemical review. Earth Sci. Rev. 19, 150.

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Meinert LD (1992) Skarns and skarn deposits. Geoscience Canada. 19:145-162.

Poulsen, K.H., R.F., and Dubé, B., 2000, Geological classification of Canadian gold deposits: Geological Survey of Canada, Bulletin 540, 106 p.

SpecMIN™, available from Spectral International, Inc., is the source for spectra used in this document.

Stuart Simmons, 2007,Northwest Mining Association Annual Meeting, Short Course on Epithermal Gold Systems