

DISTRICT	Rosebud
DIST_NO	4010
COUNTY If different from written on document	Pershing
TITLE If not obvious	Mineral content of seven samples from Rosebud Mine
AUTHOR	Allen K; Carmeron D; Kauffman R; Hughes R; Muerhoff C; Childress J
DATE OF DOC(S)	1997
MULTI_DIST Y / N?	
Additional Dist Nos:	
QUAD_NAME	Sulphur 7½'
P_M_C_NAME (mine, claim & company names)	Rosebud Mine; Accla Mining Co.; South Zone Rosebud Mining Co, LLC
COMMODITY If not obvious	gold; silver
NOTES	'XRD report; XRD printouts; correspondence' handwritten notes; clay mineralogy 28p.

Keep docs at about 250 pages if no oversized maps attached
(for every 1 oversized page (>11x17) with text reduce
the amount of pages by ~25)

Revised: 1/22/08

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CLAY MINERALOGY

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4010

1; 1:25 PM; November 22, 1997

To: Kurt Allen, Don Carmeron, and Roger Kauffman

From: Randy Hughes

Date: November 20, 1997

Subject: Mineral Content of Seven Samples from Rosebud Mine, Ref. Letter Report of Charlie Muerhoff to Roger Kauffman (7/3/97)

Discussion and Summary:

This report completes my analysis of samples RB-1 to 7, including all the planned X-ray diffraction studies—bulk powder and <4 μ m smears after air drying, ethylene glycol exposure, and heating at ~350°C and ~550°C. I revise below my initial descriptions of each sample and have added discussion about how these sorts of minerals occur and how they could be used to answer your questions. I wanted to confirm my identification of nacrite, and I also wanted a determination of the structure for the kaolinitic clay mineral in sample RB-7, which is kaolinite. (RB-1 is certainly nacrite, but we have extra X-ray diffraction (XRD) peaks that may mean we have resolved new subtleties in the nacrite structure.) I will check on my own time the structural identifications for samples RB-2-6. I previously suggested the expandables containing mica layers were 1M. I'm still not exactly sure of the exact nature of the "tosudite-like" clay mineral in RB-3 and 4. A qualitative look at the XRD patterns indicates that the smectite (montmorillonite) component is more abundant than the chlorite layer. To refine this estimate, I would have to run a series of models and reach a best fit by trial and error. If we publish this as a note, I will get help from my office mate, Dewey Moore, and we will clarify this. For your purposes, I assume the descriptions are adequate at this point. It should now be possible to answer some of the original questions that you asked. Principally, I assume you must now see 1) whether your portable infrared meter gives the same levels of discrimination, and 2) whether the clay mineral patterns are related in some way to ore occurrence and can be used to date and measure paleotemperatures in the ore zone, and/or locate and extract more ore. I am very much interested in how ore zonation is related to these clay mineral zones. Is there an easy way for me to locate these samples on an ore occurrence model?

The questions from Charlie Muerhoff that came with the samples are:

1. (What is the) Temperature of formation (for each zone).
2. If some zones contain sericite, can we get an age date?
3. (What is/are) The genetic relationship (s) of clay minerals to ore occurrence.
4. (What is) The age relationship of clay species to the hydrothermal cell.
5. Clay zonation of the vertical extent of the South Zone and why. (The number and clay mineral content of clay zones over the vertical extent of the South Zone, and what is the origin of these zones.)

My answers:

I) We can estimate the temperature of formation of each of the clay mineral zones, either by locating published work on similar clay mineral suites that includes these data or by obtaining ^{18}O isotopic determinations on a sample from each zone. Note however that we would need ^{18}O determinations on two minerals from each sample, fluid inclusion data for fluid composition, or both.

II) Most recent studies indicate that accurate K/Ar age dates can be obtained from the rectorite and mixed-layered illite/smectite (I/S) in these samples. If the K-feldspar in some of these samples is hydrothermal, it can be age dated with K/Ar, too. Some recent work has shown encouraging results from Ar/Ar methods on samples such as these. It may be necessary to size fractionate the samples so that only rectorite or I/S is present.

III, IV & V) I can't answer these questions at this time. We have the laboratory data and now we need to look at the regional and in-mine relationships and see the extent to which an answer is possible. Eric Daniels and Steve Altaner have published on the occurrences of rectorite and

tosudite in the coal measures of eastern Pennsylvania. Their study suggests that much can be learned from these types of clay mineral zones.

In my brief chat with Roger at the KT Board meeting, Roger asked whether these clay mineral zones could be used to explore for new deposits. With your closer view of things, you may be ready to answer this question, or at least to suggest follow-up work that could make an answer possible. For me to address this question, I need to understand the local and regional picture.

If you have a timetable for further work on this project, I would appreciate some rough schedules for anything that will involve me. I will be out the week of Thanksgiving and hope to be off from about January 10 to February 7. On my own time I will calculate more precise measures of the content of clay versus nonclay minerals, create better XRD patterns as "standards" for reference in the future, run our other nacrite sample and a few dickites, and further refine our understanding of the clay and nonclay minerals.

If we could get major element chemistry and loss on ignition (LOI) on $<4\mu\text{m}$ fractions and bulk samples, we could calculate percentages for each mineral. I can obtain these in the Survey, but I assume that KT Clay or Bondar-Clegg would be your normal source. Please advise me on whether these analyses can be obtained and when and how we will get them done.

I need to know if you want fine-fraction or bulk samples to calibrate the infrared spectrometer. I may have mentioned the use of dyes for detecting these zones in the mine. Do I need to search the literature for this sort of information?

A general question is whether the three major compositional variations in these samples represent distinct alteration zones in the mine. Further, does the occurrence of the tosudite-type clay mineral in samples 3 and 4 relate to subzones within the rectorite zone?

I turn next to a discussion of what geochemical mechanisms created these mineralogical zones. The few sites of this type that I have read about normally have country rock that is mostly illite, I/S, or smectite, the latter sometimes in bentonite beds. The sequence can take many paths, but illite would normally be converted first from $1M$ or $1Md$ to a $2M1$ structure. At higher temperatures, $2M1$ illites and sericites often recrystallize to coarser micas and to feldspars and other framework silicates. Smectite normally alters first to a random I/S and then to an ordered I/S. The first ordering is usually the lowest degree of nearest neighbor ordering (R1-type), which is roughly an alternating sequence of one illite layer followed by one smectite layer. In petroleum provinces, R1 I/S is an indicator of shales that are in the "oil window." R3-ordered illites usually reflect higher temperatures, and they can be thought of as three illite layers followed by one smectite layer. To the extent that we can determine it, R1 and R3 illite/smectites have $1M$ and/or $1Md$ structures. At higher temperatures, some of the occurrences in southwestern Colorado show illite:smectite ratios of about 95:5, and they show good $2M1$ structures. These samples fit the mineralogical definition of sericites, i.e., fine-grained muscovites. (Note however that geologists using optical microscopes often describe all clay-like minerals as sericite.)

Although rectorite and tosudite are fairly common, I'm not sure what proportion of hydrothermal alteration events produce these types of clay mineral zones. Also uncertain is whether illite, chlorite, kaolinite, and other types of country rock change entirely the path of reaction or simply modify reaction path to create one or more new minerals, e.g., the tosudite in samples RB-3 and 4, or the chlorite in samples RB 5 and 6. Most importantly, the actual reaction mechanism may involve discrete jumps, so that a single zone "jumps" from parent material to rectorite, without forming an intermediate I/S zone. These jumps are usually observed in hydrothermal settings, and I believe Daniels and Altaner thought they are "set" during cooling at somewhat lower temperatures than the maximum that occurred. When looking perpendicular to the ore zone, the zones are often nearly perfect outward mirror images of successively lower temperature alteration assemblages.

The kaolin group minerals are thought to respond similarly to illite and smectite altered by mechanical and thermal energy. Kaolinite is the common clay mineral in the least altered and shallowest parts of many oil fields. Dickite is commonly observed in more deeply buried and higher temperature zones. I am confident the nacrite zone bears the same relationship to the

kaolinite zone, but I'm not at all sure how or to what extent the conditions that produce nacrite are different from dickite. One interesting question is whether more detailed sampling at Rosebud would reveal an intermediate zone of dickite.

Samples 1 and 7 are very similar in being composed of abundant kaolin group clay minerals and quartz. Heating at 370°C produces a small peak at 16.3Å in sample 1 and ~16Å in 7. The glycol and heating tests on samples 2-6 refined my earlier qualitative estimates. Sample 2 is made up mostly of rectorite and quartz. Heating at 370°C produces a regular series of peaks for rectorite (10Å, 5Å, and 3.3Å, etc.) and small peaks at ~22Å, 6.6Å, and 2.8Å. However, the peaks observed for samples 3 and 4 at 12Å, 8Å, and 2.96Å are not present in sample 2. Samples 3 and 4 are similar to sample 2, except that the tosudite-like clay mineral gives a series of peaks at 21.5-24Å, 12Å, 8Å, 6.6Å, 2.96Å, and 2.8Å. I assume this is an irregular mixture of chlorite- and smectite-type layers. I estimate the composition of the clay fraction of RB-3 to be 70% rectorite, about 20% of a tosudite-like clay mineral, and 5% of a kaolinite-type mineral. The clay mineral fraction of sample RB-4 is 75% rectorite, 25% tosudite, and a trace of kaolinite-like phase.

Samples 5 and 6 contain a third type of expandable clay mineral that appears to be an R1-R3 ordered mixed-layered illite/smectite. This I/S is common as the diagenetic alteration product of smectite, and it is probably a lower-temperature phase than rectorite, tosudite, and nacrite. The clay mineral fraction of sample 5 is 75% I/S, 15% chlorite, 10% smectite, and a trace of a kaolinite-like clay mineral. The clay mineral fraction of sample RB-6 is 60% I/S, 25% chlorite, and 15% kaolinite-type clay mineral.

I suggest above that we get chemical analyses on these samples, both from <4µm fractions and bulk samples. If we need precise chemistry of single clay mineral phases, we have developed a sequential acid dissolution-ICP chemical method that might provide this information. Perhaps as soon as you read this report, we can get on a conference call and discuss further work and whether I should do library searches on the occurrences of nacrite, rectorite, and tosudite, and/or other subjects.

Mineral composition estimates for each sample:

RB-1: (descrip. in mine, Decline 1, #17 cross-cut-4650 ft; vug filling massive white clay in flow/tuff breccia and flow-banded andesite.); The XRD shows nacrite, a clay mineral that is chemically identical to kaolinite and dickite but has a slightly different structure. The structural variation may reflect formation at higher temperature, pressure, or both. In the past, several authors have suggested that nacrite records unusually high pressure or stress, under what are assumed to be the thermal conditions that produce dickite. This sample also contains lesser amounts of quartz and trace amounts of a mixed-layered clay mineral that I believe is similar to the tosudite in samples 3 and 4. This expandable is a mixture of chlorite and smectite-type layers. (I found our lab number for a nacrite from Jim Post's Silver Hill Mine (NV); it is 3604.)

RB-2: (descrip., Stope 22, main cross-cut-4652 ft; vug filling and as alteration of vesicular andesitic flow?; a common occurrence with coarse sulfides, esp., marcasite, and with >1.0 oz/t Au.) The XRD traces show a perfectly ordered, virtually pure, and possibly 1M-type mixed-layered clay mineral that is probably rectorite, a regular alternation of an expandable smectite layer with a sericite (mica-like) collapsed layer. This mineral forms in alteration zones in Arkansas and is called mountain leather in that district. A faint memory is that the mica layer is often Na-rich rather than the potassium that dominates sericite, muscovite, and illite. I called this mineral *allevardite* in my first report; rectorite has precedence and has replaced the name *allevardite*. Heating at 370°C reveals a lesser amount of a clay mineral similar to but not exactly like the tosudite-like mineral in samples 3 and 4. Quartz also is abundant, and a trace of kaolinite-type phase is present.

RB-3: (descrip., Stope 13, panel 5-4880 ft; white clay with marcasite ± pyrite occurring along low- and high-angle fractures cutting thinly flow-banded andesite and/or rhyolite in or proximal to ore. Sample from upper levels of deposit and is generally like RB-2.) The XRD traces show abundant (~70%?) rectorite, about 20% of a second mixed-layer clay mineral, and a small amount of a kaolinite-type mineral (~5%?). I have tentatively identified the second expandable mineral as

tosudite, a mixture of chlorite and smectite layers, both of which are aluminous. Chemical analyses may help distinguish these clay minerals. Like RB-2, the rectorite may have a 1M structure. Quartz is a minor nonclay mineral, and a trace of pyrite and/or marcasite seems to be present.

RB-4: (descrip., Stope 22, main cross-cut-4652 ft; white sulfide-rich clay along low- and high-angle fractures.) The XRD patterns are similar to those for RB-3, with 75% of the clay fraction as rectorite, 25% tosudite, and a trace of kaolinite-like phase. Quartz is much more abundant in the bulk sample, and I noted an unusual broad peak at 20.6° on the XRD trace. Again, a faint memory is that this is related to a special type of quartz group mineral, AKA, moganite (?). If so, there are papers in American Mineralogist that describe the occurrence of moganite.

RB-5: (descrip., Stope 13, left access cross-cut-4880 ft; propylitic-altered andesitic flow outside ore zone, with lt. green waxy clay + white clay + sulfide on fracture planes and flow partings; sample outside but proximal to upper-level ore zone.) The XRD trace of the clay fraction is 75% of a third expandable clay mineral that appears to be an R1-R3 ordered mixed-layered illite/smectite. This I/S is common as the diagenetic alteration product of smectite and perhaps kaolinite country rock, and it probably indicates a lower-temperature zone than rectorite or tosudite. The rest of the clay mineral fraction is composed of chlorite (~15%), smectite (~10%), and a trace of a kaolinite-like clay mineral. The trace of the clay mineral fraction also has a higher K-feldspar to plagioclase ratio (1 Kf:2 Pf) than the bulk XRD (1 Kf:10 Pf). On a bulk basis, the sample is rich in quartz and plagioclase (mostly albite?) with lesser calcite, minor I/S and chlorite, and trace amounts of kaolinite-type mineral and K-feldspar. Trace levels of dolomite also may be present.

RB-6: (descrip., Decline 1-4780 ft; sample from listric-normal fault footwall to majority of mineralization and alteration at Rosebud; only geochemically anomalous here, but ore 1200 ft. away.) The XRD patterns show a mineral suite similar to RB-6, but kaolinite-type:chlorite is 1:2, quartz is more abundant, and plagioclase is absent. The I/S or a separate expandable clay mineral also gives a shoulder peak at about 30Å. The clay fraction XRD indicates a composition of about 60% I/S, 25% chlorite, and 15% kaolinite-type clay mineral. The Fe to Mg+Al ratio in the chlorite appears from XRD to be high. However, heating the smear slides gives a tan gray color, which indicates a low iron content. Could there be another heavy metal such as chromium that gives this chlorite its peak ratios? It is possible too that the chlorite in samples RB- 5 and 6 is a lower-temperature alteration product related to the tosudite in samples 3 and 4.

RB-7: (descrip., Stope 23, Panel 2-4592 ft; white soapy clay on fractures with sulfide and locally as component of silica sulfide stockwork within flow/tuff breccia from deepest ore zone to date.) The XRD patterns show abundant kaolinite and quartz, with minor marcasite and K-feldspar, and trace levels of I/S. The XRD traces of the clay fraction show 40,000 counts for kaolinite and small amounts of what appears to be an I/S-like mixed-layered clay mineral.

Please let me know if you have any questions, comments, or things that I should pursue.

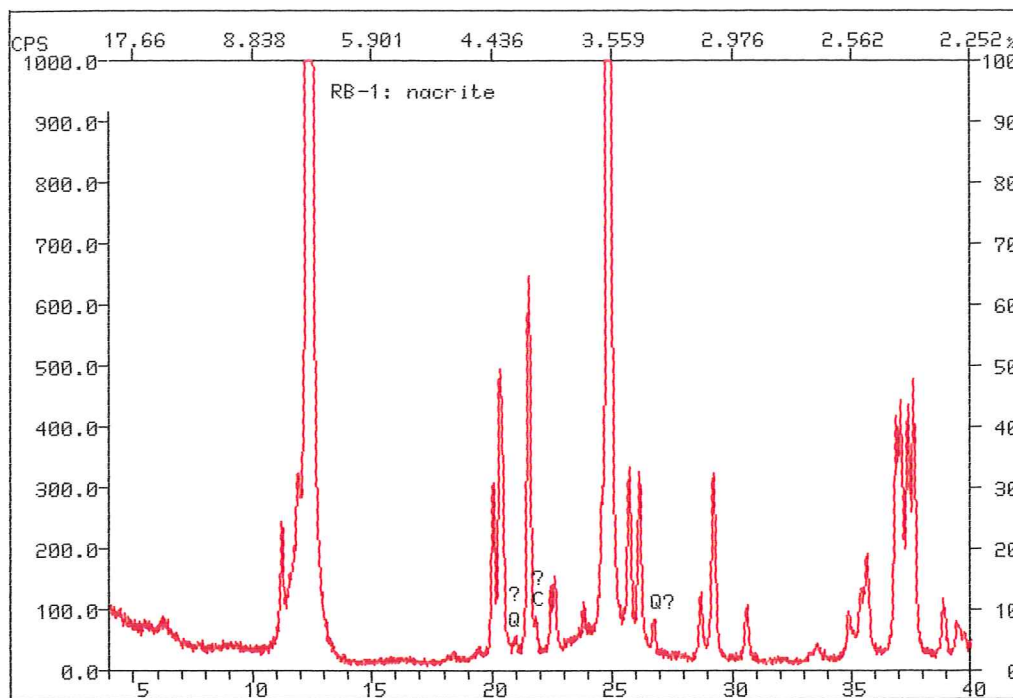


Figure 1. Random bulk XRD trace of RB-1 showing all the lines for nacrite plus two quartz (Q) lines and a possible line for cristobalite.

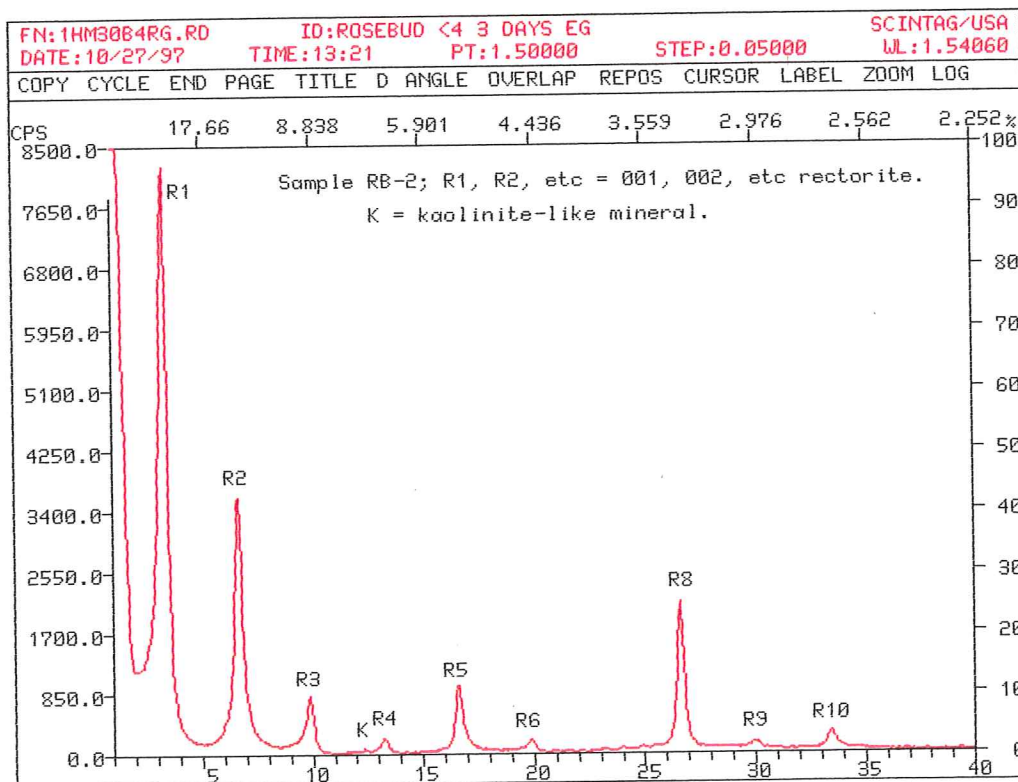


Figure 2. The XRD trace of the ethylene glycol solvated <4 μ m fraction of RB-2 showing ten orders of the peaks for rectorite.

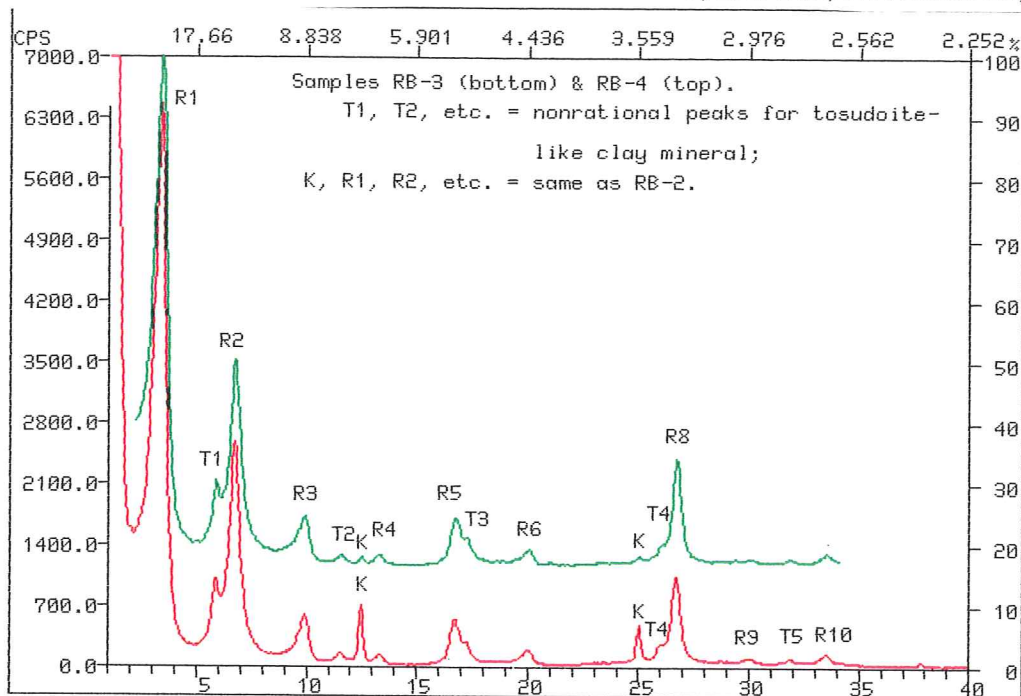


Figure 3. The XRD traces of the glycol-solvated $<4\mu\text{m}$ fractions of samples RB-3 and 4. Traces show the peaks for rectorite (R1, etc.), todsudite (T1, etc.), and a kaolinite-like (K) clay mineral.

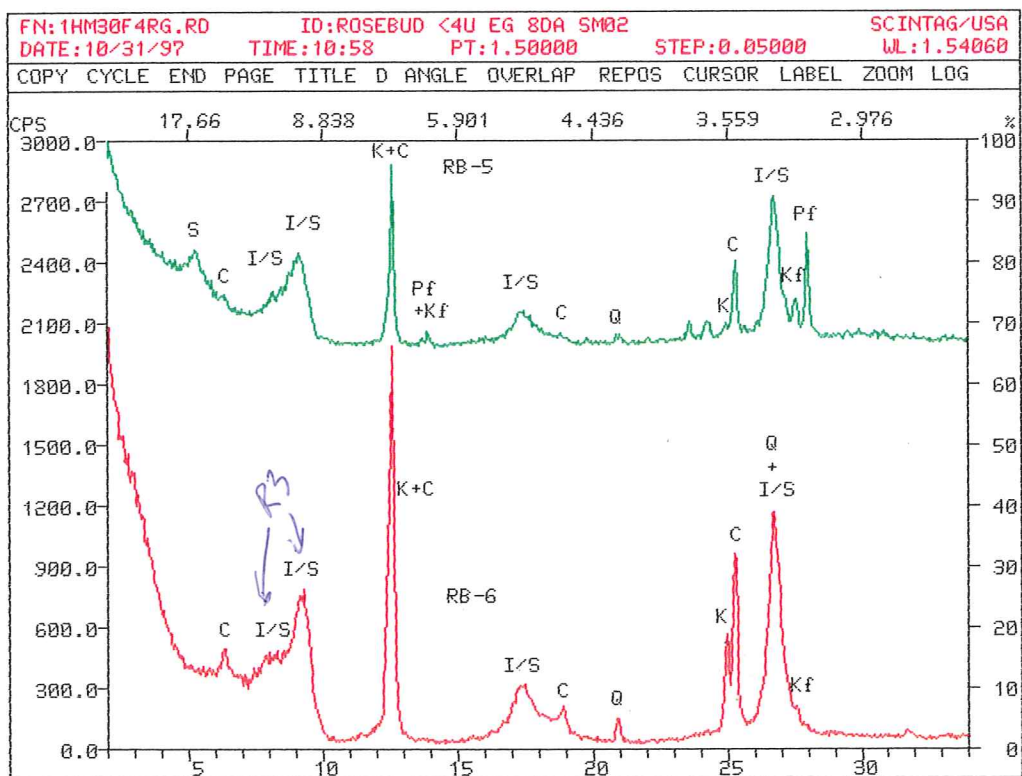


Figure 4. The XRD traces of the ethylene glycol solvated $<4\mu\text{m}$ fractions of RB-5 and 6 showing peaks for smectite (S), mixed-layered illite/smectite (I/S), a kaolinite-like mineral (K), chlorite (C), quartz (Q), K-feldspar (Kf), and plagioclase (Pf).

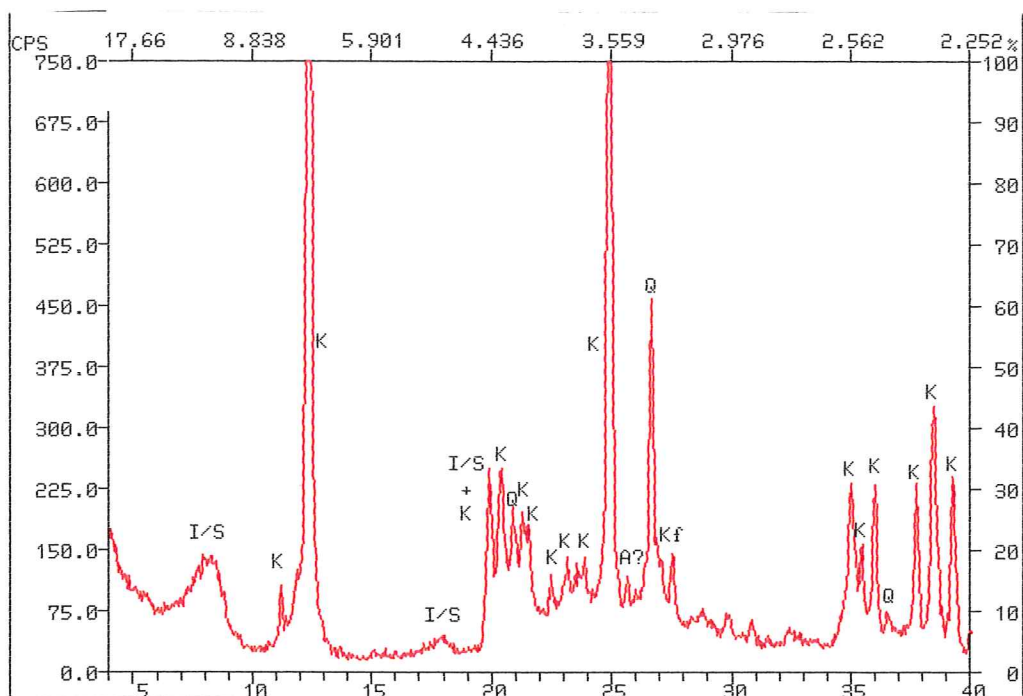


Figure 5. Random bulk XRD trace of RB-7 showing that kaolinite is the main kaolin group mineral, and I/S, quartz, K-feldspar, and anatase (A?) peaks.

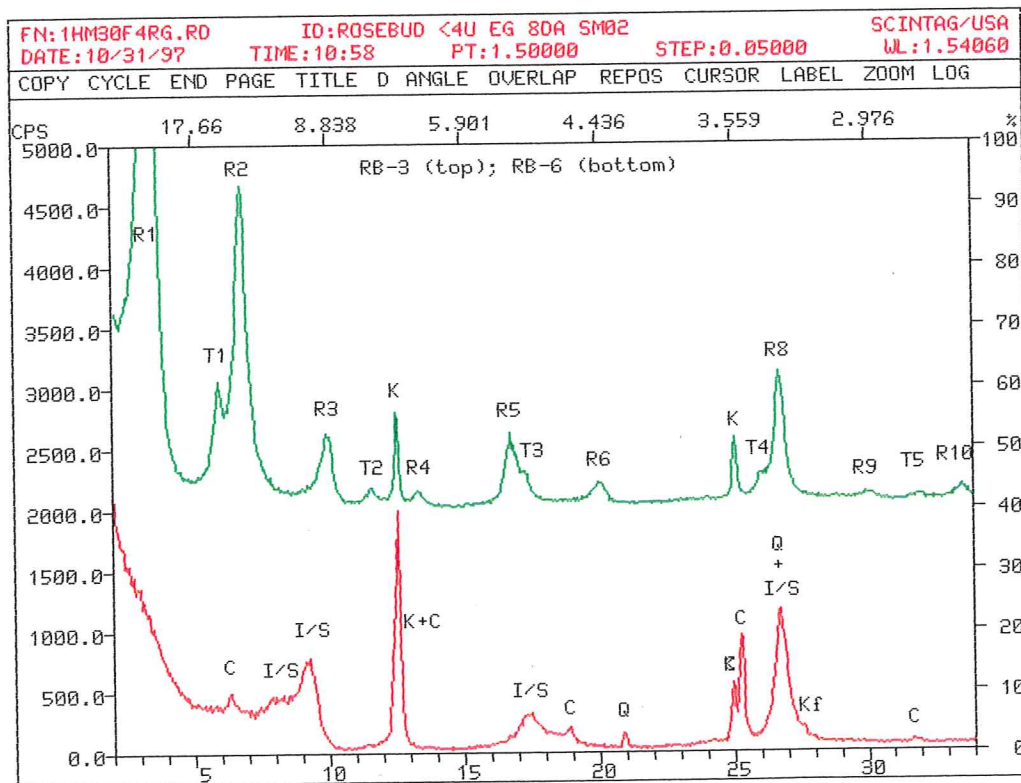


Figure 6. The XRD traces of the ethylene glycol solvated <4μm fractions of RB-3 and 6 showing the XRD peaks for the three types of expandable clay minerals— rectorite, tosudite, and I/S.

January 7, 1998

Mr. Kurt Allen, Chief Geologist
Rosebud Mining Company LLC
P.O. Box 2610
Winnemucca, Nevada 89446

Dear Kurt:

This report is my post-Rosebud visit summary and includes a bill for my expenses and a statement of the work plan we outlined. I've added a few notes to the work plan, mostly to clarify some things that we went over rather quickly. I also did some thinking about ways to form these sorts of mineral zonation patterns, and those thoughts are summarized below.

Executive Summary

I. The Pima® infrared meter proved that we could distinguish the mineral zonation that I had determined with X-ray diffraction (XRD). Questions remain about zone 3 (I/S, kaolinite, chlorite) and whether preferred orientation in the sample distorts the Pima reading. I will send XRD slides of the four zones to test orientation effects. Each clast from zone 3 had a different Pima pattern, and I will follow this up with a quick XRD of single clasts. Adding more minerals to the Pima files is needed, and we need to discuss spectral processing for Pima data.

II. The mine showed that the three or four zones [zone 1 = nacrite; 2 = rectorite-tosudite; 3 = I/S, chlorite, kaolinite; 4 (or cooler zone 1) = kaolinite and I/S] fit a model that may explain temperature and fluid chemistry, and may offer opportunities for exploration. Test cores can be run with the Pima, and we should review remote sensing by plane and/or satellite. We also noted a dark green, chlorite-rich? zone that may be transitional between zone 2 (rectorite-tosudite) and zone 3. A blackish zone may be graphite and may be equivalent to the green zone (I will XRD soon). The mineral content of zone 4 (kaolinite-rich with I/S) suggests that it occurs along fractures but at a higher level, where the fluids had cooled more. If marcasite occurs out from this kaolinite, it should be treated as a lower temperature "slice" such that nacrite and kaolinite represent nearest-fracture zones, and rectorite-tosudite and I/S represent the highest-gold zones outward from the fracture-fault.

III. The observation that some ore zones are symmetrical outward from a fracture and some are not suggests that the nonsymmetrical ones are faults and the symmetrical ones are mostly fractures. I think Marty Goldhaber's model for the Missouri metals deposits may best explain the local and regional mineralization (N. Central GSA at Rolla, MO). Marty says that the hydrological head from the uplift of the Ouchita Mountains drove fluids to depth in the northward forelands, and these fluids were enriched in H₂S and metals. As the fluids moved into Missouri, they reacted with oxidized iron in the basal Cambrian sandstone and after H₂S dropped to a few percent, the metals precipitated. This indicates that we should be able to model the solubility of metals in different salinity brines (or Marty or someone else may have already done this). At least three geochemical models (see V, below) could be invoked, but their basic geochemistry seems identical: zone 1 = low-pH, high-H₂S, hottest fluids; zone 2 = hottest zone and best ore as iron in strata precipitate H₂S, forcing precipitation of metals; zone 3 = cooler and less-altered rock where incomplete reactions led to clast-by-clast heterogeneity. Iron reduced near fractures would be precipitated as marcasite and/or carried outward, leaving a stripped suite of nacrite-kaolinite, rectorite, and tosudite. After H₂S dropped sufficiently, reduced iron in the fluids would combine with country rock to precipitate chlorite and perhaps I/S. I suspect zone 4 is a cooler equivalent of zone 1, and zone 3 mineral compositions may sometimes be an ore zone where kaolinite forms in and near fractures. If so, these zone 3 occurrences should have abundant marcasite and/or marcasite. The less argillaceous, more silicified footwall occurrence in the east part of Rosebud may represent another period of fluid movement, a fluid already stripped of H₂S, or a separate expression the same alteration event. More Pima and other data are needed from the east zone to narrow these possibilities.

We need to learn more about the unaltered host strata. Of special importance is whether they contained clay minerals or were unaltered volcanics at the time of ore emplacement.

IV. We set up a four-part plan with approximate costs on my end. A) Rosebud staff will screen as many samples as possible with the Pima, including exploration cores from other localities; B) I will immediately check individual zone 3 clasts for heterogeneity and XRD the black graphitic and greenest chloritic? samples. I will perform a literature search (~\$100) and I will revise and expand my last report to clarify a few points and add plausible models of ore genesis (~200). Early in the year, Kurt will use the Pima to pick about 24 samples for a quick XRD confirmation of Pima results, and perhaps part of the 24 samples from be from the east zone (~\$800). In a "slack" month during the spring (billed as my Hecla day/month), I will construct a final report, with a section on applications of the Pima to K-T problems. Until we know more, we deferred looking at isotopes for age or temperature measures, and we left open the possibility of quick XRD for 24-sample sets of the east zone and/or exploration samples. We also agreed that the Hecla librarian and one or more Hecla geologists may want to search the literature for the reaction chemistry suggested at Rosebud (Goldhaber or others).

V. At least three regional models seem to fit the Rosebud occurrences. My first choice would be to invoke down dip reactions that are typical of several oil provinces (Bethke at the U of Ill). These are usually driven by mountain building, such as Goldhaber's Missouri example, but diagenesis and compaction of clay minerals, as well as petroleum maturation can drive fluids upward. If so, these fluids would have migrated upward along faults, unconformities, and permeable strata, and in the process, dissolved metals. They would move upward to the west until they encountered the south bounding fault at Rosebud. Moving up along fractures and faults and permeable strata, they would deposit metals by the methods described in III. A second possibility would be to drive hot springs fluids downward from the west edge of the mountain block. A third, related possibility would be that ore fluids rose along the western block fault and then flowed down dip until intersecting the Rosebud fault. I favor the first possibility because it seems the best source of heat and H_2S .

At a later date, I will fill in some of the subtleties of the clay mineral structures and the meaning of their occurrence. If I need to address other questions, please let me know by late January.

I will be off from Saturday to January 26 for a vacation in Costa Rica. I hope this finds everything going well at Rosebud, and I hope the cigars survived the trip.

Happy New Year



Randall E. Hughes
Senior Geologist and Acting Head of Industrial Minerals & Resource Economics

cc. Roger Kauffman

University of Illinois

Address: 1304 W. Springfield Ave., Urbana, IL 61801

Telephone: (217) 333-1000 FAX: Contact sender

To:	KurtAllen	Fax:	702 623 6967
Company:	UIUC		
From:	hughes@geoserv.isgs.uiuc.edu	Date:	Wed 03/04/98
Subject:	Dewey Moore's book, etc.		
Total Pages:	2		(including cover)

ILLINOIS STATE GEOLOGICAL SURVEY

You are currently receiving a fax message from:

Name: Randall E. Hughes
Address: 615 E. Peabody Dr., Champaign, IL 61820 USA
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=46AX No: 217-244-2785 (e-mail: hughes@geoserv.isgs.uiuc.edu)

Total number of pages with cover page: 2

Please deliver to: Kurt Allen, Chief Geologist
Rosebud Mine

FAX No.: (702) 623-6967

COMMENT:

Dear Kurt:

My officemate, Dewey Moore, gave me Oxford University Press's number for ordering his book: 1-800-451-7556. The authors are D.M. Moore and R.C. Reynolds, Jr., and the title is X-Ray Diffraction and the Identification and Analysis of Clay Minerals, 1997.

We expect to receive our new detector for the X-ray instrument on March 15 or so. I will run the samples that I brought back, asap after that date.

I also will let you know how the discussions with Phoebe go on the Pima=AE.

Nice to talk with you,

Randall E. Hughes
Senior Geologist

January 7, 1998

Mr. Kurt Allen, Chief Geologist
Rosebud Mining Company LLC
P.O. Box 2610
Winnemucca, Nevada 89446

Dear Kurt:

This is my bill for the 12/17/97 visit to the Rosebud Mine.

I. 1.5 field days to Rosebud mine (1.5 @ \$750/day).....	\$1,125.00
II. Airline ticket with \$35.00 rescheduled return (\$544.00+\$35.00).....	\$579.00
III. Rental car + gas (\$61.24 + gas: \$10.25 + 10.00).....	\$81.49
IV. Motel Winnemucca and Reno (\$63.72+ \$74.69).....	<u>\$138.41</u>

A. Total Due R. E. Hughes **\$1,923.90**

***Please send payments to: Randall E. Hughes (SS No. 356-34-3431)**

**807 W. White Street
Champaign, Illinois 61820**

REH 1/8/98

86-5010-458

LA

CC: KAK

K. Allen

2

November 3, 1997

Mr. J. Gary Childress, V.P.
Industrial Minerals Division
Hecla Mining Company
6500 Mineral Drive, Box C-8000
Coeur d'Alene, Idaho 83814-1931

*Roger,
See Rosebud samples analyses
and Randy's bill attached. For your
approval.
Gary*

Dear Gary:

Zap, another month has vanished. We enjoyed our visit with you at the KT Board Meeting. I have a couple of clarifying comments that I will circulate as soon as I get round to them. We had fun in Memphis, but I'm not sure we need to return there. Next trip through, we'll spend the time visiting KT Mississippi. I also have some interesting ideas for you and Bob on the dioxin front. As soon as I get Rosebud samples finished or if I can grab 30 minutes, I'll email and fax you the dioxin thoughts. And I will try and remember to add ideas on mushroom growing.

Please find below my bill for October. I haven't had time to finish a couple of things that I want to try on the Chinese kaolins. That should allow a better comparison to KT's Georgia kaolins. I think the report I sent Lamar Long and Eric Westbrook took care of their current needs, and putting off the follow-up for a month won't hurt. It could even help with new ideas, etc.

I spent my Hecla time this month on Roger's samples from the Rosebud Mine. I rushed a preliminary analysis so we could discuss them in Mississippi. I've just about finished them, and they are about as unique a set of samples as I have seen. I attach at the end of this letter my 11/4/97 update on the Rosebud samples. An additional twist on the Rosebud samples was Don Cameron's mention of using a portable infrared spectrometer in the Rosebud Mine. They are using this instrument in-mine identification of different clay mineral alteration zones. We should discuss at some point the potential value of this instrument in ball clay and kaolin mines. I'll also try and remember to mention it to Bob.

My new Acting Section Head role for Industrial Minerals & Mineral Economics Section began November 1. Roger told me once that the biggest problem with TQM and similar management approaches is the need for a manager to seek to eliminate the need for their job (mostly because they don't trust that the next job up the ladder will be there). With my bent on the Cosmos, I will be more than happy to aim at the TQM standard. Further, any advice from you on this job would be very much appreciated. I learned immediately after my acceptance memo that there are some HRO problems, obviously an oversight....

We don't know yet whether or when I may visit Rosebud Mine. I'll let you know that and any other changes that pop up.

Best wishes,

Randy

Randall E. Hughes
Senior Geologist

RB-1: (descrip. in mine, Decline 1, #17 cross-cut-4650 ft; vug filling massive white clay in flow/tuff breccia and flow-banded andesite.); The XRD shows nacrite, a clay mineral that is chemically identical to kaolinite and dickite but has a slightly different structure, which may reflect

formation at higher temperature, pressure, or both. This sample also contains lesser amounts of quartz and trace amounts of a mixed-layered clay mineral that I believe is similar to the less abundant expandable clay mineral in samples 3 and 4. This expandable may be a non-regular mixture of chlorite and smectite (montmorillonite)-type layers. It also occurs in trace amounts with a kaolinite-type mineral in sample 7. (I found our number for a nacrite from Jim Post's Silver Hill Mine (NV); it is 3604.)

RB-2: (descrip., Stope 22, main cross-cut-4652 ft; vug filling and as alteration of vesicular andesitic flow? (sic); a common occurrence with coarse sulfides, esp., marcasite, and with >1.0 oz/t Au.) XRD shows a perfectly ordered, virtually pure, and possibly 1M-type mixed-layered clay, probably rectorite-like with 1 smectite layer alternating with a sericite (mica)-like collapsed layer. A faint memory is that the mica layer is often Na-rich rather than the potassium that dominates sericite, muscovite, and illite. I called this mineral allevardite in my first report; rectorite has replaced this name. Quartz also is abundant, and a trace of kaolinite-type phase is present.

RB-3: (descrip., Stope 13, panel 5-4880 ft; white clay with marcasite \pm pyrite occurring along low- and high-angle fractures cutting thinly flow-banded andesite and/or rhyolite in or proximal to ore. Sample from upper levels of deposit and is generally like RB-2.) XRD shows abundant (~70%?) rectorite, about 20% of a second mixed-layer mineral, and a small amount of kaolinite-type mineral (~5%?). I have very tentatively identified the second expandable mineral as todsudite, a mixture of chlorite and smectite layers, both of which are aluminous. Chemical analyses may help distinguish these clay minerals. Like RB-2, the rectorite, todsudite, or both may have a 1M structure. Quartz is a minor nonclay mineral, and a trace of pyrite and/or marcasite seems to be present.

RB-4: (descrip., Stope 22, main cross-cut-4652 ft; white sulfide-rich clay along low- and high-angle fractures.) XRD shows similar pattern as RB-3, with 75% of the clay fraction as rectorite, 25% todsudite, and a trace of kaolinite-like phase. Quartz is much more abundant and I noted an unusual broad peak at 20.6° on the XRD trace. Again, a faint memory is that this is related to a special type of quartz group mineral, AKA, moganite (?).

RB-5: (descrip., Stope 13, left access cross-cut-4880 ft; propylitic-altered andesitic flow outside ore zone, with lt. green waxy clay + white clay + sulfide on fracture planes and flow partings; sample outside but proximal to upper-level ore zone.) XRD of the clay fraction is 75% of a third expandable clay mineral that appears to be an R1-R3 ordered mixed-layered illite/smectite (I/S). This I/S is common as the diagenetic alteration product of smectite, kaolinite, or both, and it is probably a lower-temperature phase than rectorite or todsudite. The rest of the clay mineral fraction is composed of chlorite (~15%), smectite (~10%), and a trace of a kaolinite-like clay mineral. The clay mineral trace also has a higher K-feldspar to plagioclase ratio (1 Kf:2 Pf) than the bulk XRD (1 Kf:10 Pf). On a bulk basis, the sample is rich quartz and plagioclase (mostly albite?) with lesser calcite, minor I/S and chlorite, and trace amounts of kaolinite-type mineral and K-feldspar. Trace levels of dolomite also may be present.

RB-6: (descrip., Decline 1-4780 ft; sample from listric-normal fault footwall to majority of mineralization and alteration at Rosebud; only geochemically anomalous here, but ore 1200 ft. away.) The XRD shows a mineral suite similar to RB-6, but kaolinite-type:chlorite is 1:2, quartz is more abundant, and plagioclase is absent. The I/S or a separate expandable clay mineral also gives a shoulder peak at about 30Å. The clay fraction XRD gives about 60% I/S, 25% chlorite, and 15% kaolinite-type clay mineral. I will check soon to try and determine the relative ratio of Fe to Mg and Al in the chlorite. It is possible that chlorite is the lower-temperature equivalent of the todsudite in samples 3 and 4.

RB-7: (descrip., Stope 23, Panel 2-4592 ft; white soapy clay on fractures with sulfide and locally as component of silica sulfide stockwork within flow/tuff breccia from deepest ore zone to date.) XRD shows abundant kaolinite-type mineral and quartz, with minor marcasite and K-feldspar, and trace levels of I/S and talc or pyrophyllite. Clay fraction XRD shows 40,000 counts for kaolinite-type mineral and small amounts of a todsudite-like mixed-layered clay mineral (?). Heating tests in the next few days will clarify this identification.

November 1, 1997

Mr. Gary Childress, V.P.
Industrial Minerals Division
Hecla Mining Company
6500 Mineral Drive, Box C-8000
Coeur d'Alene, Idaho 83814-1931

Dear Gary:

This is my bill for October 1997.

HECLA MINING CO.

I. Prep & X-ray — 7 samples from Rosebud mine (18.5 hr. @ \$75/hr)..... \$1,387.50

A. Total Due R. E. Hughes \$1,387.50

*Please send payments to: Randall E. Hughes (SS No. 356-34-3431)
807 W. White Street
Champaign, Illinois 61820

REH 11/3/97

8650-86-5010-458

REH

11/21/97

University of Illinois

Address: 1304 W. Springfield Ave., Urbana, IL 61801

Telephone: (217) 333-1000 FAX: Contact sender

To:	KurtAllen	Fax:	702 623 6967
Company:	UIUC		
From:	hughes@geoserv.isgs.uiuc.edu	Date:	Thu 11/06/97
Subject:	RB-1 to RB-7 Results		
Total Pages:	5	(including cover)	

\$ 7500⁰⁰

Need Detailed Scope of work.

244-0080

Larry Hughes:

Don want through it.

- seems to corroborate zoning mix I/S to

Kaolinite in stores.

- You could get incred. Buy complicated parameters.

- Plan to get h.m. out here

ILLINOIS STATE GEOLOGICAL SURVEY

You are currently receiving a fax message from:

Name: Randall E. Hughes
Address: 615 E. Peabody Dr., Champaign, IL 61820 USA
Telephone: (217) 244-0080
Date: November 6, 1997
=46AX No: 217-333-2830 (e-mail: hughes@geoserv.isgs.uiuc.edu)

Total number of pages with cover page: 4

Please deliver to: Kurt Allen or Don Cameron
Hecla Mining Co. Rosebud Mine
FAX No.: (702) 623-6967

COMMENT:

To: Kurt Allen, Don Cameron, and Roger Kauffman
=46rom: Randy Hughes
Subject: Second Report on Samples RB1-7 from Rosebud Mine

This report completes my initial look at samples RB-1 to 7. Each diagnostic test gave some new and unexpected results, so I have delayed this report for a few days to finish the full set of X-ray diffraction studies- bulk powder and <4=B5m smears after air drying, ethylene glycol exposure, and heating at ~350=B0C and ~550=B0C. I've revised below my initial description of each sample and have left the locations and bulk mineral descriptions from my first report.

On my own time, I will run carefully prepared bulk powders of samples 1 and 7. I want to make standard reference patterns of the nacrite in sample 1, and I still am not sure which type of kaolin group mineral is in sample 7. These determinations should be done by early next week, and I will then send you a report with labeled XRD traces and any final comments on the samples. I also may rerun sample RB-2 to see if the mixed-layering is perfect enough to meet the criteria for calling it rectorite. Note that I called this mineral alleverdite in my first report. My office mate Dewey Moore has just published the second edition of his book on X-ray diffraction of clays, and they use the latest nomenclature, which replaces alleverdite with rectorite.

A general question is whether the three major compositional variations in these samples represent distinct alteration zones in the mine. Further, does the occurrence of the tosudite-type clay mineral in samples 3 and 4 relate to subzones in the mine? I also will be interested in whether your portable infrared instrument can distinguish nacrite from other kaolin group minerals. Related to that is whether sample RB-7 gives a different infrared signature from RB-1. Note here that the minor rectorite(?) clay mineral in sample 7 could make it appear different from sample 1.

Samples 1 and 7 are very similar in being composed of abundant kaolin group clay minerals and quartz. Heating at 370=B0C produces a small peak at 16.3=C5 in 1 and ~16=C5 in 7.

The glycol and heating tests on samples 2-6 refined my earlier qualitative estimates. Sample 2 is made up mostly of rectorite and quartz. Heating at 370=B0C produces a regular series of peaks for rectorite (10=C5, 5=C5, and

3.3=C5, etc.) and small peaks at $\sim 22=C5$, $6.6=C5$, and $2.8=C5$. However, the peaks observed for samples 3 and 4 at $12=C5$, $8=C5$, and $2.96=C5$ are not present in sample 2. Samples 3 and 4 are similar to sample 2, except that the tosudite-like clay mineral gives a series of peaks at $21.5-24=C5$, $12=C5$, $8=C5$, $6.6=C5$, $2.96=C5$, and $2.8=C5$. I assume this is an irregular mixture of chlorite- and smectite-type layers. I estimate the composition of the clay fraction of RB-3 to be 70% rectorite, about 20% of a tosudite-like clay mineral, and 5% of a kaolinite-type mineral. The clay mineral fraction of sample RB-4 is 75% rectorite, 25% tosudite, and a trace of kaolinite-like phase. Again, the detection of these differences by your infrared instrument will be of interest.

Samples 5 and 6 contain a third type of expandable clay mineral that appears to be an R1-R3 ordered mixed-layered illite/smectite (I/S). This I/S is common as the diagenetic alteration product of smectite, kaolinite, or both, and it is probably a lower-temperature phase than rectorite, tosudite, and possibly even nacrite. The clay mineral fraction of sample 5 is 75% I/S, 15% chlorite, 10% smectite, and a trace of a kaolinite-like clay mineral. The clay mineral fraction of sample RB-6 is 60% I/S, 25% chlorite, and 15% kaolinite-type clay mineral.

In my brief chat with Roger at the KT Board meeting, Roger asked whether these clay mineral zones could be used to explore for new deposits. It appears that we must answer your original questions and determine whether your infrared can the infrared unit detect these variations in clay mineral composition. Also, are the major and minor clay mineral compositional zones related to the hydrothermal patterns? Your infrared instrument may be the method of choice. Some progress also has been made in using chemical dyes for field identification of the expandable clay minerals in these ores.

If possible, I suggest we can get chemical analyses on the $<4=B5m$ fractions of these samples. If you need precise chemistry of single clay mineral phases, we have developed a sequential acid dissolution-ICP chemical method that can provide this information. I also mentioned in my first report that the clay fractions of samples 2-7 could be K/Ar age dated, and oxygen isotopes on the $<4=B5m$ fraction of each of the seven samples could be determined to obtain estimates of temperature and chemical composition of the hydrothermal fluids. Perhaps as soon as you read this report, we can get on a conference call and discuss further work and whether I should do a library search on the occurrences of nacrite and rectorite.

Summary of composition estimates for each sample:

RB-1: (descrip. in mine, Decline 1, #17 cross-cut-4650 ft; vug filling massive white clay in flow/tuff breccia and flow-banded andesite.); The XRD shows nacrite, a clay mineral that is chemically identical to kaolinite and dickite but has a slightly different structure. The structural variation may reflect formation at higher temperature, pressure, or both. This sample also contains lesser amounts of quartz and trace amounts of a mixed-layered clay mineral that I believe is similar to the less abundant expandable clay mineral in samples 3 and 4. This expandable may be a non-regular mixture of chlorite and smectite (montmorillonite)-type layers. (I found our lab number for a nacrite from Jim Post's Silver Hill Mine (NV); it is 3604.)

RB-2: (descrip., Stope 22, main cross-cut-4652 ft; vug filling and as

alteration of vesicular andesitic flow? (sic); a common occurrence with coarse sulfides, esp., marcasite, and with >1.0 oz/t Au.) XRD shows a perfectly ordered, virtually pure, and possibly 1M-type mixed-layered clay mineral that is probably rectorite, a regular alternation of a smectite layer with a sericite (mica)-like collapsed layer. This mineral forms in alteration zones in Arkansas and is called mountain leather in that district. A faint memory is that the mica layer is often Na-rich rather than the potassium that dominates sericite, muscovite, and illite. I called this mineral alleverdite in my first report; rectorite has precedence and has replaced alleverdite. Heating at 370=B0C reveals a small amount of a mineral similar to but not exactly like the tosudite-like mineral in samples 3 and 4. Quartz also is abundant, and a trace of kaolinite-type phase is present.

RB-3: (descrip., Stope 13, panel 5-4880 ft; white clay with marcasite =B1 pyrite occurring along low- and high-angle fractures cutting thinly flow-banded andesite and/or rhyolite in or proximal to ore. Sample from upper levels of deposit and is generally like RB-2.) XRD shows abundant (~70%?) rectorite, about 20% of a second mixed-layer mineral, and a small amount of kaolinite-type mineral (~5%?). I have very tentatively identified the second expandable mineral as todsudite, a mixture of chlorite and smectite layers, both of which are aluminous. Chemical analyses may help distinguish these clay minerals. Like RB-2, the rectorite may have a 1M structure. Quartz is a minor nonclay mineral, and a trace of pyrite and/or marcasite seems to be present.

RB-4: (descrip., Stope 22, main cross-cut-4652 ft; white sulfide-rich clay along low- and high-angle fractures.) XRD shows similar pattern as RB-3, with 75% of the clay fraction as rectorite, 25% tosudite, and a trace of kaolinite-like phase. Quartz is much more abundant and I noted an unusual broad peak at 20.6=B0 on the XRD trace. Again, a faint memory is that this is related to a special type of quartz group mineral, AKA, moganite (?). If so, there are papers in American Mineralogist that describe the genesis of moganite.

RB-5: (descrip., Stope 13, left access cross-cut-4880 ft; propylitic-altered andesitic flow outside ore zone, with lt. green waxy clay + white clay + sulfide on fracture planes and flow partings; sample outside but proximal to upper-level ore zone.) XRD of the clay fraction is 75% of a third expandable clay mineral that appears to be an R1-R3 ordered mixed-layered illite/smectite (I/S). This I/S is common as the diagenetic alteration product of smectite, kaolinite, or both, and it is probably a lower-temperature phase than rectorite or tosudite. The rest of the clay mineral fraction is composed of chlorite (~15%), smectite (~10%), and a trace of a kaolinite-like clay mineral. The clay mineral trace also has a higher K-feldspar to plagioclase ratio (1 Kf:2 Pf) than the bulk XRD (1 Kf:10 Pf). On a bulk basis, the sample is rich in quartz and plagioclase (mostly albite?) with lesser calcite, minor I/S and chlorite, and trace amounts of kaolinite-type mineral and K-feldspar. Trace levels of dolomite also may be present.

RB-6: (descrip., Decline 1-4780 ft; sample from listric-normal fault footwall to majority of mineralization and alteration at Rosebud; only geochemically anomalous here, but ore 1200 ft. away.) The XRD shows a mineral suite similar to RB-6, but kaolinite-type:chlorite is 1:2, quartz is more abundant, and plagioclase is absent. The I/S or a separate expandable clay mineral also gives a shoulder peak at about 30=C5. The clay fraction XRD seems to contain about 60% I/S, 25% chlorite, and 15% kaolinite-type clay mineral. The Fe to Mg and Al ratio in the chlorite appears from XRD to be high. However, heating the smear slides gives a tan gray color, which indicates a low iron content. Is there another heavy metal such as chromium that gives this chlorite its peak ratios? It also is possible that chlorite is a lower-temperature alteration product related to the tosudite in samples 3 and 4.

RB-7: (descrip., Stope 23, Panel 2-4592 ft; white soapy clay on fractures with sulfide and locally as component of silica sulfide stockwork within flow/tuff breccia from deepest ore zone to date.) XRD shows abundant kaolinite-type mineral and quartz, with minor marcasite and K-feldspar, and trace levels of I/S and talc or pyrophyllite. Clay fraction XRD shows 40,000 counts for kaolinite-type mineral and small amounts of what I believe is an I/S-like mixed-layered clay mineral.

Please let me know if you have any questions or comments.

Randy Hughes

To: Kurt Allen, Don Cameron, and Roger Kauffman
October 23, 1997
=46rom: Randy Hughes
Subject: Preliminary Report on Samples RB1-7 from Rosebud Mine

Don, as we discussed, this report gives some preliminary qualitative comments on my X-ray diffraction (XRD) analyses of the seven samples. I also will make a few comments in reference to the questions that came with the samples (from Charlie Muerhoff). Those questions are:

1. Temperature of formation.
2. If some zones contain sericite, can we get an age date?
3. The genetic relationship of clay minerals to ore occurrence.
4. The age relationship of clay species to the hydrothermal cell.
5. Clay zonation of the vertical extent of the South Zone and why.

The qualitative mineralogical description of the bulk samples:

RB-1: (descrip., Decline 1, #17 cross-cut-4650 ft; vug filling massive white clay in flow/tuff breccia and flow-banded andesite.); XRD shows nacrite, a mineral that is chemically identical to kaolinite and dickite, but has a slightly different structure, which may reflect higher temperature and/or pressure of formation. Sample also contains lesser amounts of quartz and trace amounts of smectite-montmorillonite and a mixed-layered clay mineral.

RB-2: (descrip., Stope 22, main cross-cut-4652 ft; vug filling and as alteration of vesicular andesitic flow? (sic); a common occurrence with coarse sulfides, esp., marcasite, and with >1.0 oz/t Au.) XRD shows ordered, possibly 1M-type mixed-layered clay, probably alleverdite-like with 1 smectite layer alternating with a sericite-like collapsed layer. Quartz also is abundant, and a trace of kaolinite-type phase may be present.

RB-3: (descrip., Stope 13, panel 5-4880 ft; white clay with marcasite =B1 pyrite occurring along low- and high-angle fractures cutting thinly flow-banded andesite and/or rhyolite in or proximal to ore. Sample from upper levels of deposit and is generally like RB-2.) XRD shows mixed-layered mineral similar to RB-2, with small amount of kaolinite-type mineral and trace of talc or pyrophyllite? Quartz is a minor nonclay mineral, and a trace of pyrite and/or marcasite may be present.

RB-4: (descrip., Stope 22, main cross-cut-4652 ft; white sulfide-rich clay along low- and high-angle fractures.) XRD shows similar pattern as RB-3, but quartz is much more abundant and alleverdite seems to be broadened?

RB-5: (descrip., Stope 13, left access cross-cut-4880 ft; propylitic-altered andesitic flow outside ore zone, with lt. green waxy clay + white clay + sulfide on fracture planes and flow partings; sample outside but proximal to upper-level ore zone.) XRD shows abundant quartz and plagioclase (mostly albite?) with lesser calcite, minor mixed-layered illite/smectite (I/S) and chlorite, and trace amounts of kaolinite-type mineral and K-feldspar. Trace levels of dolomite also may be present.

RB-6: (descrip., Decline 1-4780 ft; sample from listric-normal fault footwall to majority of mineralization and alteration at Rosebud; only geochemically anomalous here, but ore 1200 ft. away.) XRD shows mineral suite similar to RB-6, but kaolinite-type:chlorite is 1:2, quartz is more abundant, and plagioclase is absent.

RB-7: (descrip., Stope 23, Panel 2-4592 ft; white soapy clay on fractures with sulfide and locally as component of silica sulfide stockwork within flow/tuff breccia from deepest ore zone to date.) XRD shows abundant kaolinite-type mineral and quartz, with minor marcasite and K-feldspar, and trace levels of I/S, talc or pyrophyllite, and smectite?

I prepared <4=B5m smears of the 7 samples and <8=B5m and 8~20=B5m fractions =

of

RB-1. In all cases this eliminates most of the quartz, feldspar, calcite and pyrite/marcasite from the finer fractions and gives a better view of the clay minerals. I have run the air-dried smear samples last night, and I will run the ethylene glycol treated samples tomorrow (Friday). I will run a random powder pack of RB-1, 2, and 7 next week. These will precisely identify the nacrite, alleverdite, and kaolinite-type mineral in RB-7. The <4=B5m smears should resolve talc-pyrophyllite identifications by early next week, too.

I will be happy to return size-fractionated samples to calibrate your infrared instrument. I also may be able to send one sample of nacrite from Jim Post's work at Silver Hill Mine, and we probably have one or two dickites, and at least one sample of Arkansas alleverdite-mountain leather. Unless I hear otherwise, I will assume that qualitative identifications of the nonclay minerals are adequate at this time.

We should do a library search on the occurrences of nacrite and alleverdite. Should I do that, or will your librarian at Coeur d'Alene do that?

To answer the questions:

- 1) It is possible that oxygen isotopes of two minerals from each sample could give an accurate temperature and water chemistry on alteration fluids. If we can get full chemistry for the <4=B5m samples or their acid extracts from Kentucky-Tennessee Clay, my lab, or a similar lab, we might be able to say more about fluid chemistry. For this and the age dating question, I will chat tomorrow with a returning Ph.D. from our lab; his 1996 thesis was on age and temperature of formation of diagenetic illite in the Illinois Basin (Georg Grathoff, U of I, Urbana/Champaign).
- 2) If they are as they seem, micaceous layers in RB 2, 3, 4, 5, and 6 could be age dated by K/Ar or less likely Ar/Ar. Georg can tell me more tomorrow.
- 3) There seem to be clay mineral zones relating to ore =B1 alteration zones. I don't have a good enough view of 3-D picture to discuss this yet.
- 4) Same answer as 3.
- 5) Same as 3 and 4. Questions 3, 4, and 5 are parts of the same question- To what extent do clay and nonclay minerals differ as a result of alteration, ore deposition-mineralization, or both? (By-the-by, I assume from Muerhoff's report that "alteration zones" have a distinctly different meaning from ore zones. Is this correct? Can you tell me more about how the deposit is altered and formed?

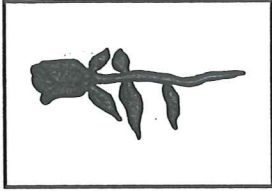
I will forward second view of samples early next week, about Tuesday.

Please let me know if you have any questions or if I need to go in other directions.

More soonest....

RANDALL HUGHES - Clay Study Report

- 7 Samples too few to Define ~~the~~ ZONATION PATTERN of clay surrounding & within ORE ZONES.
- Information on Clay Relationships - Chem/TEMP/P_H/EA/etc.



The Rosebud Mining Company LLC

P.O. Box 2610
Winnemucca, NV 89446
Phone (702) 623-6912
Fax (702) 623-6967
Hecla Mining Co. - Manager of Mining

COPY

Memorandum to: Roger Kauffman
From: Charlie Muerhoff
Date: July 3, 1997
RE: Rosebud Clay Mineralogy Study

Enclosed are seven (7) clay samples from Rosebud that we would like to have examined. The samples were collected from both the upper and lower levels of the South Zone of the deposit and represent clay occurrences in both ore and waste.

Besides the obvious question of 'what are the clay species?', I hope you may be able to provide answers or insight to a few other questions:

- temperature of formation.
- I suspect some of the clay is sericite; is it possible to get an age date?
- genetic relationship to ore.
- the various clay species relative age relationship as part of the hydrothermal cell.
- clay 'zonation' over the vertical extent of the South Zone and why?

Included is a sample list with sample location, elevation, and a brief description. Also enclosed is an excerpt from the feasibility study which summarizes the mineralization and alteration of the Rosebud Deposit South Zone.

Thank you once again for assisting us in this study. Please do not hesitate to contact me (or Kurt Allen) if you have any questions.

Charlie

Rosebud Mine
Samples for Clay Mineralogy Identification

Sample RB-1 Location: Decline 1, #17 cross-cut, 4650 ft. elevation.

HAECITE { Massive white clay commonly observed to fill vugs in flow/tuff breccia and flow-banded andesite and rhyolite, either within or proximal to ore zone. This particular occurrence of clay is normally devoid of visible sulfide, but is generally a good indicator of proximity to ore grades.

Sample RB-2 Location: Stope 22, main access cross-cut, 4652 ft. elevation.

RECTORITE { White clay occurring as vug-filling and also locally appears to be the result of total alteration of a vesicular andesitic flow? within one of the main ore zones. This is a very common occurrence of clay, which normally contains coarse sulfides (marcasite-dominant) and is often spatially (and genetically?) related to >1.0 oz/t Au grades.

Sample RB-3 Location: Stope 13, Panel 5, 4880 ft. elevation.

70% RECTORITE
20% TOBSUBITE
5% KAOLINITE { White clay, normally with sulfide (marcasite ± pyrite), which occurs along high- and low-angle fractures which cut a thinly flow-banded andesite and/or rhyolite either within or proximal to ore grade mineralization. This sample was taken from the upper levels of the deposit and generally appears to have the same hand sample characteristics of sample RB-2 (above).

Sample RB-4 Location: Stope 22, main access cross-cut, 4652 ft. elevation.

75% RECTORITE
25% TOBSUBITE { White, sulfide-rich clay occurring along high-and low-angle fractures. Same as samples RB-2 and RB-3?.

Sample RB-5 Location: Stope 13, left access cross-cut, 4880 ft. elevation.

75% ILLITE/smectite
15% CHLORITE
10% SMECTITE { Propylitic-altered andesitic flow, outside of ore zone, with light green waxy clay + white clay + sulfide on fracture planes and flow partings. This sample was taken outside of, but proximal to, the upper-level ore zone.

Sample RB-6 Location: Decline 1, 4780 ft. elevation.

60% I/S
25% CHLORITE
15% KAOLINITE { Sample was taken from a major listric-normal fault which is the footwall to the majority of the mineralization and alteration at Rosebud. In this particular location, the fault is only geochemically anomalous, but ore grade mineralization does occur approximately 1,200 feet away from this sample location along strike.

Sample RB-7 Location: Stope 23, Panel 2, 4592 ft. elevation.

KAOLINITE "TYPE" { White, 'soapy' clay which occurs on fractures with sulfide and locally as a component of silica sulfide stockwork within a flow/tuff breccia. This sample was taken from the deepest portion of the ore zone accessed to date.

acquired from recent drilling and development at Rosebud suggest these northeast structures are 'scissor-like' in their displacement; exhibiting normal displacement to the south and reverse displacement to the north due to the rotational, listric movement along the South Ridge Fault. The apparent 'hinge-point' between the two directions of displacement is a zone of intense shearing, alteration, and block rotation, with high-grade gold-silver mineralization which comprises much of the high-grade "chimney" area of the deposit.

Geologic interpretive modelling in 1994 also revealed the existence of several previously undefined east-west to northwesterly ($\pm N80^\circ W$) mineralized structural trends that may post-date and offset the South Ridge Fault. These trends are the location of the Far East and Southeast exploration targets.

3.2.3 MINERALIZATION AND ALTERATION

The Rosebud Deposit is a low-temperature, epithermal, quartz-sericite, precious metal deposit which is primarily hosted in volcanic rocks of Miocene age.

The majority of the gold occurs in two dominant grain size populations of ± 10 microns and ± 350 microns, with some grains exceeding 700 microns in diameter. Silver occurs over an extremely large range of grain sizes (pyrargyrite (Ag_3SbS_3) crystals up to 1/4 inch in diameter were observed in drill core). The overall silver-to-gold ratio of the deposit is 9.5:1, while the silver to gold ratio in the ore grade portion of the mineral occurrence is 6.2:1.

The deposit has been divided into three (3) distinct spatially separated zones, based on location and distinctly different styles of mineralization: the South, East, and North zones. Figures 3.2.1-1 through 3.2.1-5 illustrate the geometry of the Rosebud deposit.

South Zone

The Rosebud South Zone is located entirely on the hanging wall of the South Ridge Fault and is hosted entirely in the LBT unit of the Kamma Mountain Volcanics.

Alteration associated with precious metal deposition within the LBT unit of the Kamma Mountain volcanics displays vertical and lateral zonation. In general, there is a core of moderate to intense argillic and potassic alteration within the ore zone itself. Extending upward (proximal to structures) and outward (along favorable stratigraphic horizons) is an intermediate zone of propylitic alteration (carbonate-chlorite dominant) which is overprinted by a 'halo' of a quartz/chalcedony-clay alteration assemblage. A

hematite-carbonate assemblage comprises an extreme distal alteration package to the mineral deposit. The boundaries of these alteration assemblages are not sharp, as the different alteration zones clearly overlap, suggestive of alteration overprinting due to a fluctuating hydrothermal cell.

Alteration began with the diagenetic devitrification of glassy volcanic fragments to quartz, K-feldspar and albite. Early sericitic alteration of both feldspars appears to accompany the introduction of disseminated pyrite, marcasite, sphalerite, and galena. The sericite often contains minor amounts of iron, and therefore, can be classified as illite.

The earliest major mineralizing episode is characterized by stockwork and dissemination of quartz + pyrite + marcasite ± chalcopryite ± electrum, with traces of arsenopyrite ± sphalerite ± galena ± pyrrhotite ± anatase ± tetrahedrite-tennantite. Fractures containing this mineral assemblage may be the same age of, and feeders for, the disseminated sulfides and sericitization.

A later set of fractures contain the mineralizing assemblage consisting chiefly of manganese- or iron-rich calcite + silver sulfosalts (pyrargyrite, miargyrite, stylopyrite, proustite, and polybasite) + silver selenides (naumannite, aguilarite) + silver sulfide (acanthite) + native silver + auriferous silver (Au content < 30%) + and silver-rich electrum (Au content > 30%). Calcite in these veins appears to corrode earlier pyrite and marcasite. While alteration of marcasite to pyrite proceeded from the margins of the marcasite blades inward toward the center, calcite or kaolinite commonly replaces the core of the marcasite blades. The calcite-silver veining phase appears to often incorporate fragments of earlier quartz-sulfide mineralization.

The precious-metal stages of mineralization were followed by minor veining and open-space filling of barite, particularly on the hanging wall of precious metal mineralization. This was followed by the latest stage of mineralization, consisting of veinlets of kaolinite which cut across calcite veins, and replace both the calcite and earlier marcasite; it is uncertain whether the kaolinite is hydrothermal or supergene. It is possible that a portion of the chlorite formed instead of kaolinite where iron was locally available.

In the south half of the South Zone, precious metals occur as a component of stratabound stockwork (the result of preferential brecciation of the more brittle volcanoclastic units) and disseminated within several stratigraphic members. Stratabound ore grade mineralization (stockworked and disseminated) ranges from ten (10) to locally 60 feet in thickness. Higher gold grades are normally associated with chloritized and pyritized planar- and convoluted-laminated tuff and vesicular, flow-banded tuff, and with

potassic-altered (alunite-adularia) tuff breccia. There is also a region within one of the flow-laminated tuff/tuff breccia members in which high gold and silver grades are associated with carbon, occurring on fracture surfaces and as a portion of the breccia matrix. Metallurgical tests indicate the carbon is not active and therefore not detrimental to precious metal recoveries. It appears the carbon had been emplaced in the LBT unit as a result of remobilization from the underlying graphitic metasediment basement during the epithermal mineralizing process.

Mineralization in the north half of the South Zone occurs strongly structurally controlled, with lesser stratabound control. Several mineralized, northeast-trending, high-angle structures coalesce and define a zone of intense shearing and alteration. High-grade gold (+1.0 opt) and silver mineralization occur within this zone over a vertical extent of 220 feet along the structures and within two preferentially mineralized lithologies. This zone, referred to as the 'chimney', also contains lower ore grades in stockwork and as a disseminated mineralized 'halo' in nearly all stratigraphic units of the host rock. As currently defined, the 'chimney' contains approximately 40% of the minable gold ounces contained within the entire Rosebud Deposit.

East Zone

The Rosebud East Zone, hosted entirely within the Dozer Tuff unit, is situated on the footwall of the South Ridge Fault and is characterized by pervasive silica replacement of the volcanic host rock. The majority of the high gold grades (>0.50 opt) occur on the immediate footwall of the fault, with thicknesses ranging from ten (10) to 40 feet. Overall gold mineralization above 0.10 gold ounces per ton reaches thicknesses of up to 100 feet in the East Zone.

Alteration within the Dozer Tuff unit of the Kamma Mountain volcanics is dramatically different from the assemblages observed in the LBT unit. In the deposit area, the top of the Dozer Tuff is fault-bounded by the listric-normal South Ridge Fault, which acts as an upper boundary to alteration and mineralization in the East Zone. Mineralization in the Dozer Tuff is associated with pervasive silicification; consisting of chalcedony and locally vein quartz. Protolith rock textures are commonly totally replaced by sulfide-bearing silica. Silicification persists downward from the South Ridge Fault from 30 to 120 feet, but does not extend upward into the hanging wall of the fault. There is a gradational boundary between the zone of silicification and a strongly propylitic to moderately argillic alteration package which occurs below the zone of silicification.

Like the alteration and mineralization within the LBT unit, alteration within the Dozer Tuff unit began with the diagenetic devitrification of glassy volcanic fragments to quartz,