With additional appropriations sought for irrigation purposes at the Bobcat Ranch, Eureka Moly and its affiliates will consume nearly all of the available groundwater resources (the estimated perennial yield) in the Kobeh Valley Hydrographic Basin, leaving little additional water for appropriation by others in the foreseeable future. At present, aggressive mineral exploration is underway in multiple locations throughout Kobeh Valley west of the Mt Hope Project by entities other than Eureka Moly. It is conceivable that additional groundwater appropriations will be sought in the relatively near future. Mining is often considered a temporary use of the water, but there is a history of "temporary" mining rights being extended *ad infinitum*. As a result, the effects of mining operations on the groundwater regime can be felt for several human generations, well after the project ceases. We entreat the State Engineer to carefully consider the not-so-temporary nature of a project that will affect Eureka County for several generations, even after the project ends.

It is the County's intent to encourage and facilitate the Nevada State Engineer's effort in ensuring the project "is done right." We anticipate that an appreciation of the potential changes arising from the project and recognition of the uncertainty of the predicted impacts will help guide the Nevada State Engineer's actions regarding the project proponents' water-rights applications. Assuming the State Engineer approves Eureka Moly's water rights, at the very least, we anticipate that the County's actions will incite the State Engineer to require development and execution of a comprehensive monitoring, management and mitigation (3M) program that incorporates active involvement and input from all stakeholders, particularly Eureka County as the local governmental entity. A comprehensive monitoring program that serves to protect senior water rights holders, other stake holders and the environment has been a condition of approval by the State Engineer of water-rights applications in other areas. Because of the extent and magnitude of the predicted drawdown from the Mt Hope Project, extending over a large area in Kobeh Valley and into adjacent hydrographic basins, a comprehensive 3M program is imperative so that changes related to the mine's groundwater resource exploitation can be identified early. That way, effective management and mitigation measures grounded in scientific principles and analyses can be implemented before the changes result in undesirable or irreversible impacts either to the environment or senior water rights holders. It must be recognized that some mitigation measures themselves may need to be regulated by the State Engineer. They also may require analysis under the National Environmental Policy Act. Furthermore, the plausible mitigation measures should be the subject of analysis before the project is allowed to commence. In reality, many mitigation measures may be too economically or ecologically restricting to be effectively implemented (i.e., discharging groundwater to the surface to simulate stream flow to a fishery).

The numerical groundwater flow model presented by the mine's consultants has undergone several iterations since first reviewed by Eureka County's consultant team in 2008. A number of the comments and recommendations from the

County's team have been incorporated into the model by the mine's consultants and they have acknowledged that our input resulted in a more robust, defensible model. However, we still have some unease and concerns with the most recent version of the model and the associated report. That is the subject of the current memoranda prepared by the County's team. Each team member has prepared a memorandum that incorporates their unique perspective.

Discussion

Missing Points of Diversion

Plate 1, which is supposed to depict points of diversion of permits, vested and decreed rights, and pending applications within a 30-mile radius of Mount Hope, inexplicably omits the points of diversion for the latest round of permit applications (Numbers 79911-79942), which is the subject of the December 2010 administrative hearing before the State Engineer.

Bias interjected into the model and report

In our opinion, the model and report project a bias which does nothing more than justify the Mount Hope Project as proposed, rather than present a neutral assessment of potential impacts to water, water-dependent resources, and senior water rights. Generally, the report accentuates conclusions or postulates hypotheses that benefit the project and downplays results that may be construed as counter to the mine's interests. It is our opinion that the mine's consultants should be vigilant not to interject "Eureka Moly knows best" bias into their assessment of potential impacts. Perhaps, if the mine had not distributed pamphlets to Eureka County residents (ref.: *A Eureka Moment* & *Mt. Hope Tour* - prepared by Eureka Moly, 2010) that clearly downplayed and misrepresented potential impacts, we would not be quite so sensitive to the issue of bias. These pamphlets have used terms such as "equivalent to a strong garden hose" to describe the inter-basin flow between Kobeh Valley and southern Diamond Valley. The mine's groundwater model suggests this inter-basin flow is approximately 1,583 acre-feet per year, which amounts to approximately thirteen percent of the total recharge to southern Diamond Valley, which is ***not*** trivial. Quite frankly, it would have been better if the mine refrained from hyperbole and did not attempt to downplay potential impacts because that tactic is unscientific and fosters mistrust.

Specific instances of the bias presented in the report are discussed below.

<u>*More recharge from precipitation than assumed for the model*</u>

Section 3.2.1 of the Model Report (Montgomery, *et al.*, 2010) states ". . . the PRISM data suggest generally greater quantities of water in the overall hydrologic system compared with the Reconnaissance Series Reports." To

begin with, the term "PRISM data" is misleading. I believe they could have used a more correct term or phase such as "PRISM estimates" or "distribution of recharge estimated using PRISM" so that it is clear the distribution of precipitation is an estimate based on a complex algorithm, not measured values (data).

If there is in fact more water (recharge from precipitation) "in the system," there must be an equivalent increase in discharge, either as ET or inter-basin flow. For Kobeh Valley, phreatophyte areas are fairly well established as are ET rates, such that the current estimate of ET for Kobeh Valley is thought to be quite good. As a result, increased recharge from precipitation in Kobeh Valley must be accompanied by increased flow out of the basin to Diamond Valley because "Groundwater not discharged in Kobeh Valley flows eastward into Diamond Valley" (*ibid.*, Sec. 3.4).

*The projected 10-ft drawdown contour as **the** metric for determining potential impacts to springs, streams and wells and associated water rights*

Ten (10) feet of drawdown calculated by the model was adopted by the mine's consultant team as ***the*** threshold for determining which wells, springs and other water resources within the model domain have a potential to be impacted by the mine's groundwater extractions (*ibid.*, Section 4.1.3.4). That is, only wells, springs or other resources situated within the projected maximum extent of the modeled 10-ft drawdown contour (refer to Figure ES-5 of Montgomery, *et al.*, 2010, inserted below) were considered as having a potential to be impacted by the mine. To put it another way, springs, wells or perennial streams just beyond the projected 10-ft drawdown contour where there is, say 9.4 feet of drawdown, for example, are considered to not have any potential to be impacted by the mine's pumping. This threshold downplays the potential for impacts.

The scientific basis behind the use of the 10-ft drawdown contour as a bellwether of "impacted water rights" categorized in the report is not explained, other than that it has apparently been used for other groundwater flow model analyses in Nevada supporting environmental assessments of mining projects. The basis for this threshold appears to be an assumption that natural (seasonal and long-term climatic) variations will occlude anthropogenic causes unless the change is greater than 10 feet. That may be true for data compiled from a sparse monitoring network where only quarterly measurements are taken and very little

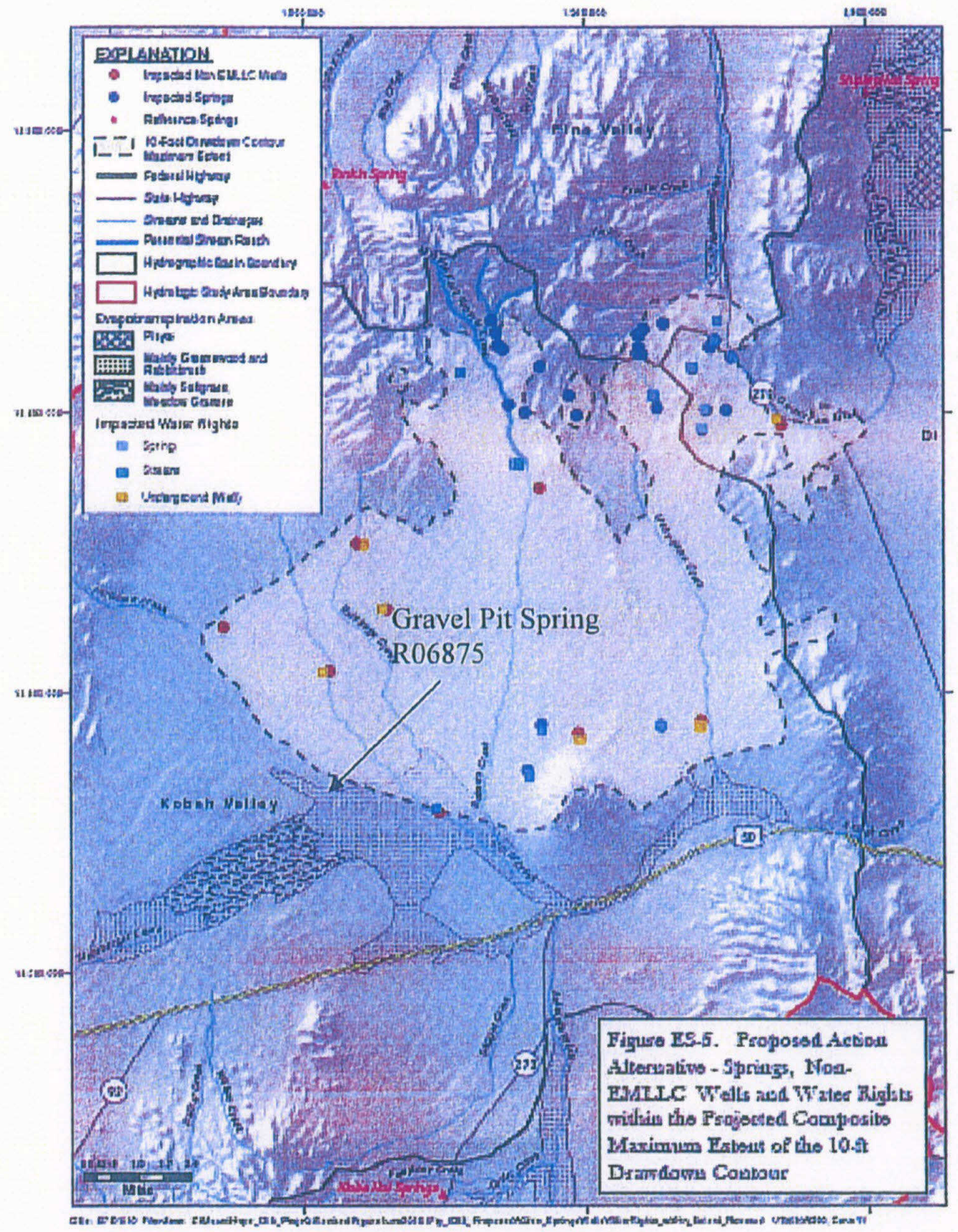

Figure ES-5. Proposed Action Alternative - Springs, Non-EMLLC Wells and Water Rights within the Projected Composite Maximum Extent of the 10-ft Drawdown Contour

historical data are available to clearly establish trends, but not for a comprehensive monitoring network that includes a large amount of data acquired from a network that incorporates data loggers to collect high-frequency measurements. I personally have installed and maintained monitoring networks where water-level changes of a few 10ths of a foot have been clearly linked to a specific pumping stress miles away, once you separate out other influences such as earth tides, train and vehicle traffic, barometric pressure, recharge events and a host of other outside influences.

The notion that drawdown less than 10 feet is indicative of no potential for impacts is inconsistent with the model results where less than 10 feet of drawdown captures evapotranspiration from phreatophytes in Kobeh Valley. A key tenant of Nevada Water Law is that the State incites appropriators to capture natural discharge and place it to a higher use. If groundwater exploitation does not capture discharge from ET in Kobeh Valley, then by default the mine's groundwater extractions could only capture discharge from Kobeh Valley to Diamond Valley via the carbonate rocks, incite more groundwater flow from adjacent basins, or rely solely on capturing storage. Figure ES-5 (*ibid.*) clearly shows that the vast majority of the phreatophyte area where ET will be captured in response to the mine's groundwater extractions is beyond the 10-ft contour, i.e., less than 10 feet of drawdown. It makes sense that, if five feet of drawdown or less will capture water discharged to ET (an impact), and the estimates of phreatophyte-discharge capture are credible, then five feet of drawdown or less may impact existing resources, particularly springs. For that reason, we believe that a map depicting the maximum extent of the 5-ft drawdown contour resulting from the mine's pumping provides a better sense of the water rights that might be impacted by the mine's groundwater pumping.

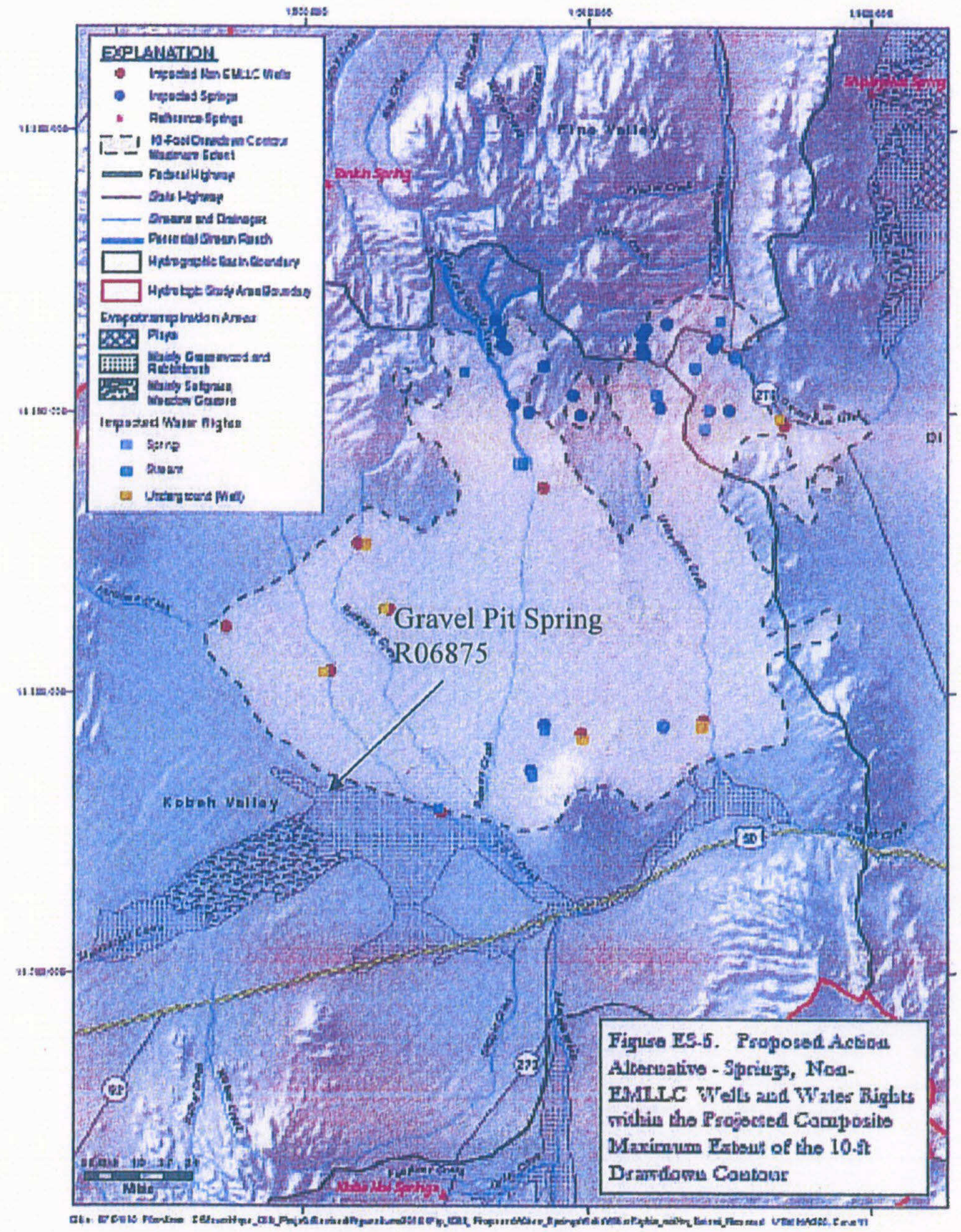

Figure ES-5. Proposed Action Alternative - Springs, Non-EMLLC Wells and Water Rights within the Projected Composite Maximum Extent of the 10-ft Drawdown Contour

Figure DCB-1 further illustrates our opinion that 10 feet of drawdown should not be universally applied as a measure of whether or not impacts will occur. There is a federal reserved water right (R06875), which in some instances continues to expand for Gravel Pit Spring at an area referred to as Grub Flat, north of Bean Flat. This reserved water right is for 400 cattle, 40 horses, 350 sheep and 57 deer and antelope and has a priority date of 1926. It is the primary water source for livestock and wildlife in the Santa Fe/Ferguson allotment. The spring is located outside of the maximum extent of 10-ft drawdown contour determined by the mine's consultants, so it was not considered to have any potential to be impacted. The spring exists because the shallow water table intersects the land surface near the former gravel pit. A drawdown as little as five feet will almost certainly impact spring flows and this important supply of water pumping ceases.

The County's team developed a map using output from the regional model (Montgomery, *et al.*, 2010) that depicts the extent of the 5-ft drawdown contour at the end of mining (year 2055). Figure DCB-1 illustrates the 5-ft drawdown contour for both the mine-only pumping and the cumulative action pumping scenarios. Comparison with Figure ES-5 clearly shows much of the area where phreatophyte discharge is captured as a result of the mine's pumping is situated in areas where drawdown is less than five feet and certainly less than 10 feet.

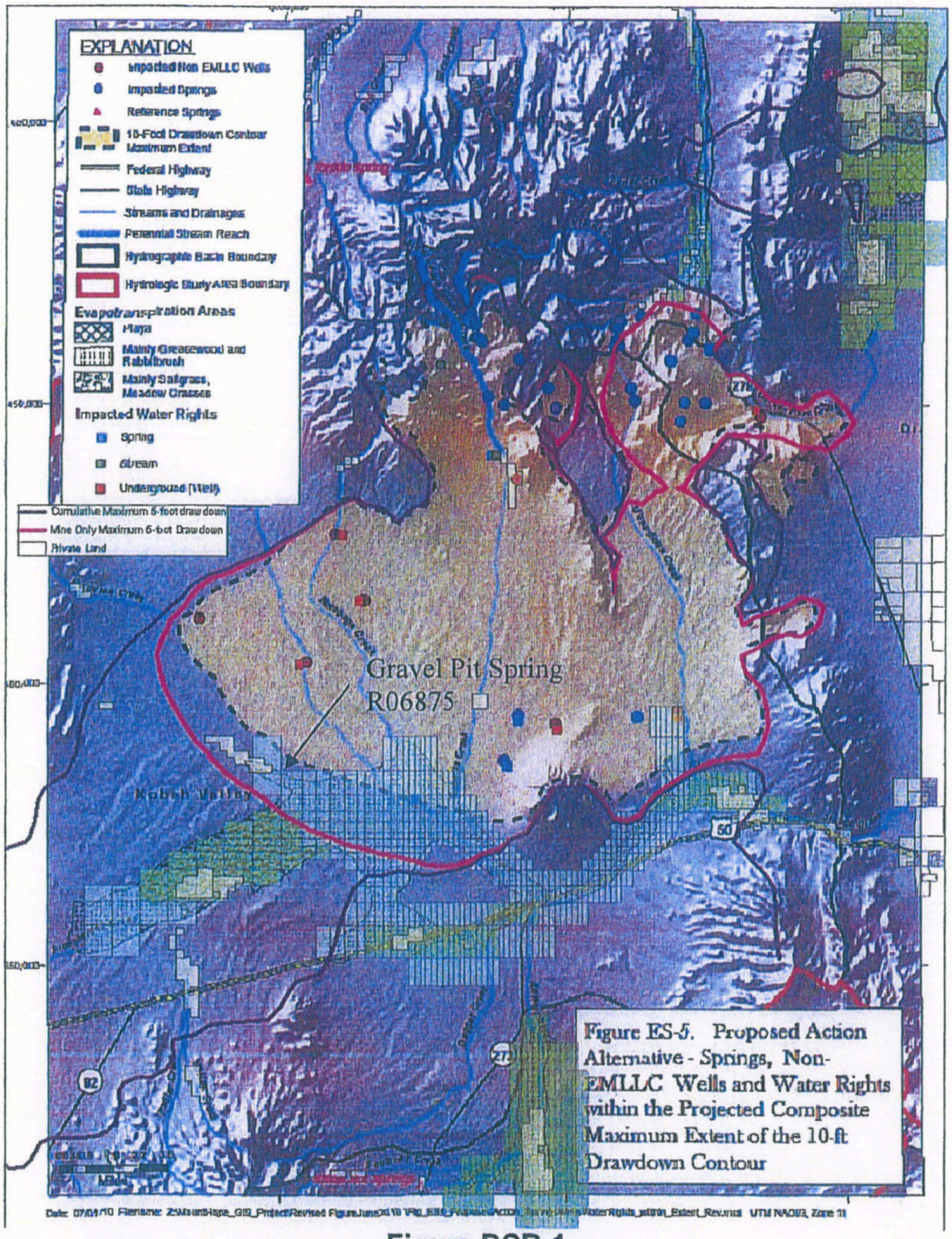

Figure DCB-1
(Figure ES-5 with 5-ft year 2055 contour added)

As a point of clarification the 5 and 10 ft contours provided in Figure DCB-1 are for year 2055. This differs from the 10-ft contour in ES-5, which is a composite of the maximum extent of the 10-ft contour for different times after mining concludes.

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square miles (Armstrong, 1970). Ash was deposited and reworked by streams in the Whistler Mountain area, and formed the stratified tuffaceous sandstones to the west of Devils Gate. Volcanic mud flows gave rise to the massive conglomeratic tuffs.

The structural features that were responsible for the ultimate formation of Devils Gate, were Oligocene east-west normal faults. Late Oligocene to Miocene normal faulting uplifted Whistler Mountain and also initiated a period of erosion. This erosion produced debris which filled depressions and buried the Oligocene volcanic rocks. The flanking pediments were formed during this time and were subsequently buried by rounded gravels and cobbles of Vinini chert, Mississippian clastics, and Devonian limestone. Pebbles to boulders of quartz-monzonite were also deposited on the pediment, when the Whistler Mountain laccolith was unroofed and exposed to erosion, probably in the Tertiary. During this time, a large fresh water lake was present in the western valley and extended onto the pediment.

Late Miocene to early Pleistocene faulting, which trends north-northwest, is responsible for the large, fault-line scarp just west of Devils Gate and may also be partially responsible for continued uplift of Whistler Mountain. The Paleozoic rocks in Diamond Valley were also probably uplifted at this time.

The faults, which defined Diamond Valley, date from Pliocene to Pleistocene time, and trend north-south or east-northeast (Masursky, 1960). In section 30, T. 23 N., R. 54 E., 7,485 ft of undifferentiated Tertiary strata was penetrated by drilling before entering Devonian sediments in Diamond Valley (Campbell and Hebrew, 1957). Eastward tilting of Whistler Mountain occurred in post-early Pleistocene time (Roberts and others, 1967).

In Pleistocene time the valleys surrounding Whistler Mountain were filled with pluvial lakes, which often fluctuated in size. At times when the weather was cooler and more humid, periglacial features formed on the mountain. It was during this time that the lakes reached their maximum size. Eventually the level of the lake in Kobeh and Antelope Valleys breached the col at Devils Gate and drained eastward into Diamond Valley. Continued lake level fluctuations in Diamond Valley eventually allowed Diamond Lake to erode Railroad Pass and drain into the Humboldt River system. Pediments were dissected during low stands of the lakes. Today, the pediment is still being dissected, and Slough Creek still drains Kobeh Valley eastward into Diamond Valley through Devils Gate.

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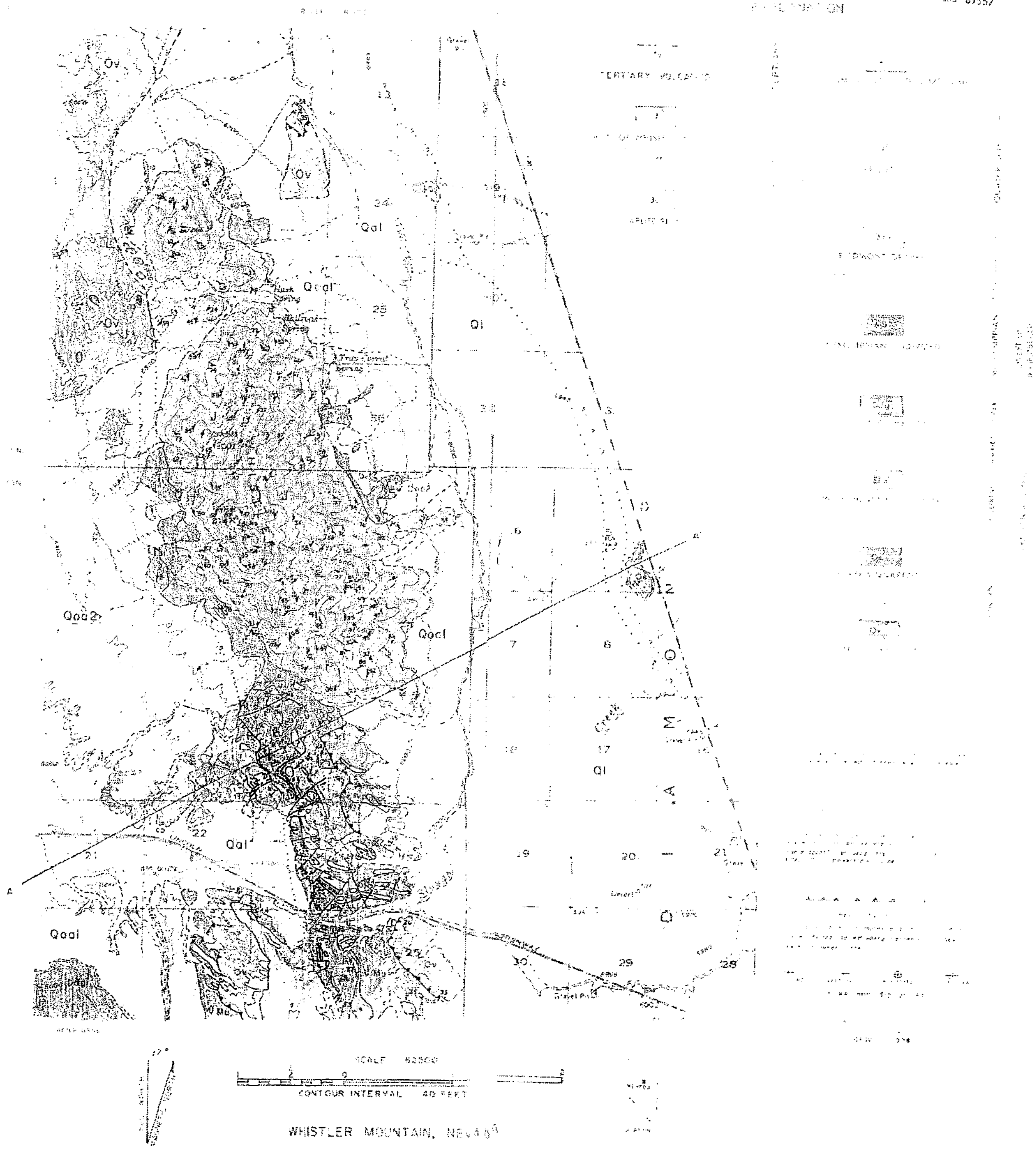
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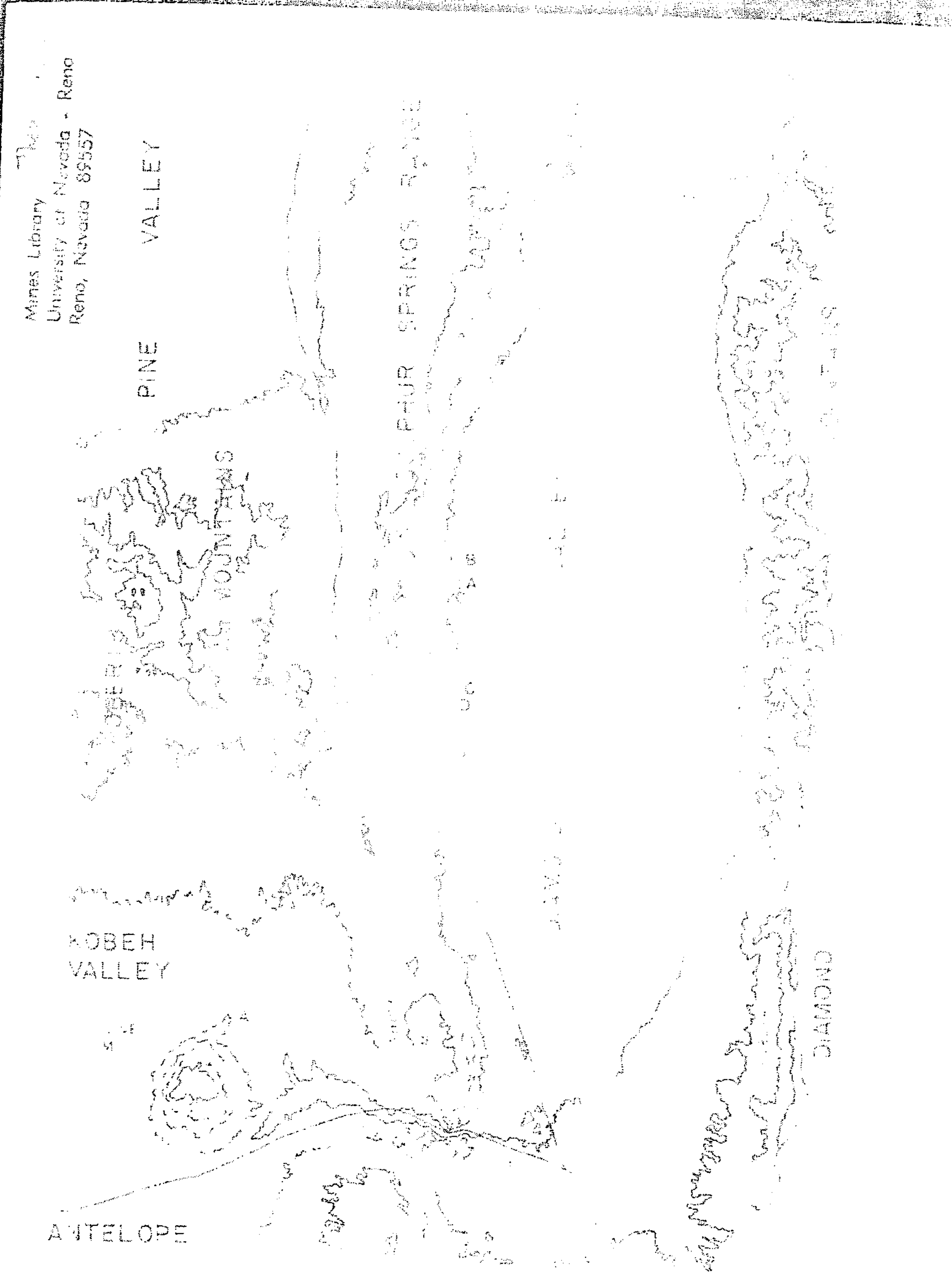
WHISTLER MOUNTAIN, NEVADA



A - spit

B - beach deposits

C - headland

D - stacks

Pleistocene Lake Diamond attained an elevation of approximately 6000 ft. Pleistocene lake in Kobeh and Antelope Valleys attained an elevation of approximately 6300 ft.

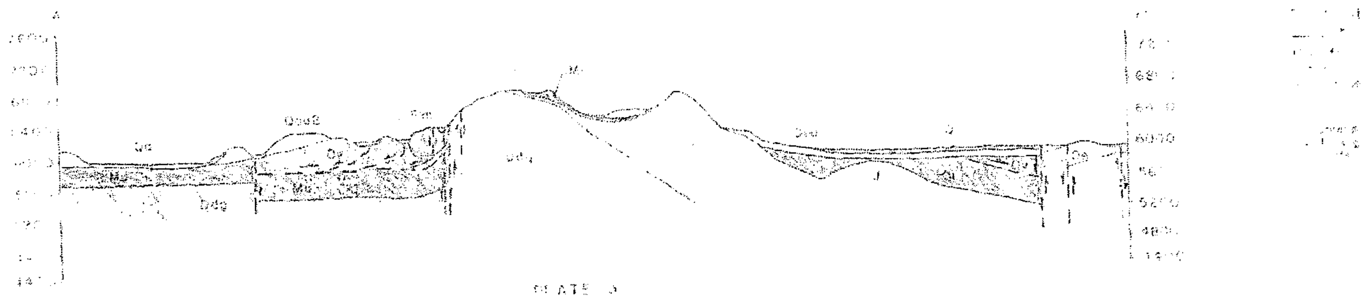
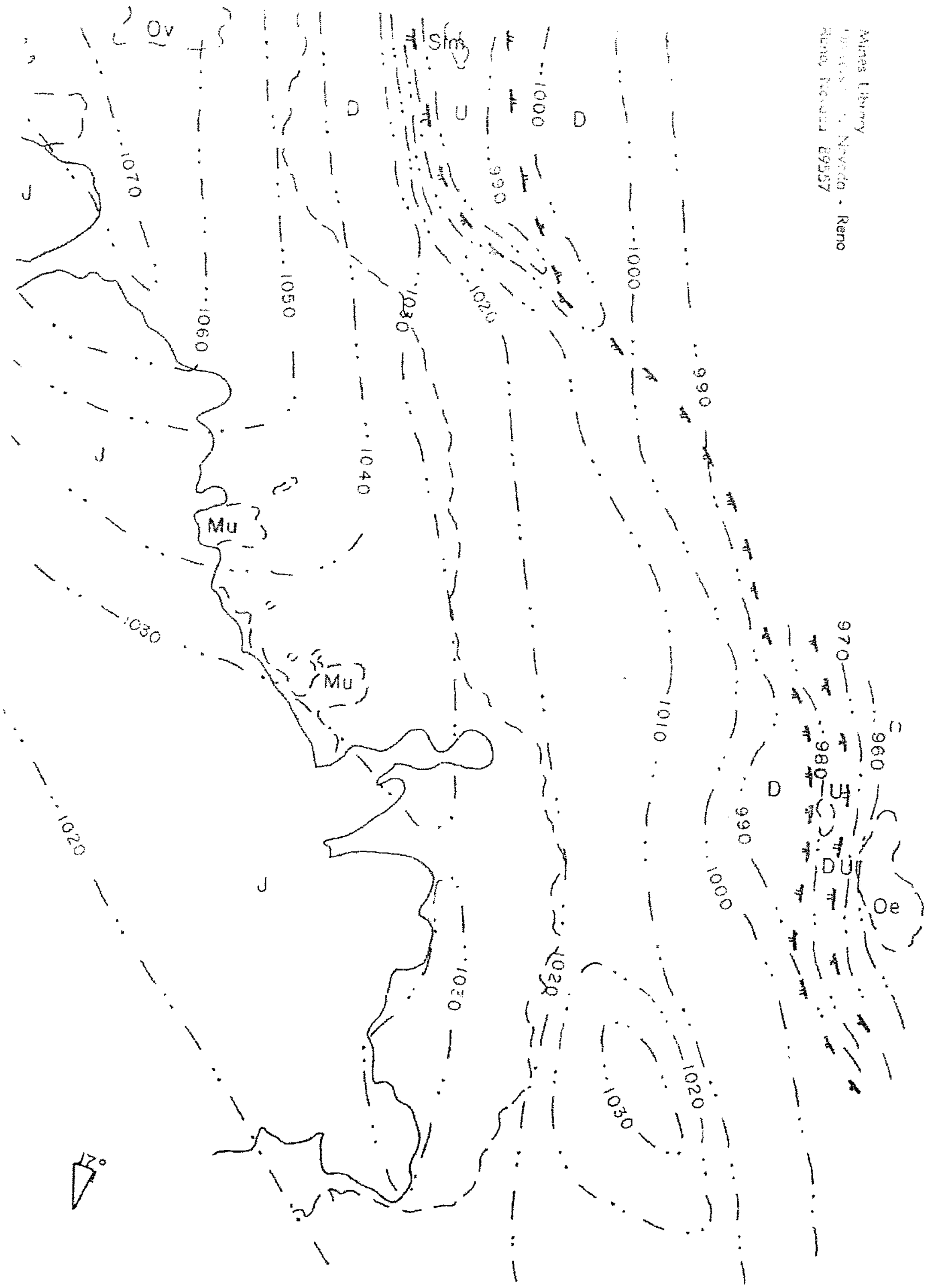


PLATE 5



Scale 1:62,500

Plate 4. Magnetic map and interpretation. Contours in gammas.

STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF WATER RESOURCES
BEFORE JASON KING, P.E., STATE ENGINEER

In the Matter of Application Nos:

72695, 72696, 72697, 72698, 73545, 73546,
73547, 73548, 73549, 73550, 73551, 73552,
74587, 75988, 75989, 75990, 75991, 75992,
75993, 75994, 75995, 75996, 75997, 75998,
75999, 76000, 76001, 76002, 76003, 76004,
76005, 76006, 76007, 76008, 76009, 76483,
76484, 76485, 76486, 76744, 76745, 76746,
76802, 76803, 76804, 76805, 76989, 76990,
77171, 77174, 77175, 77525, 77526, 77527,
77553, 78424, 79911, 79912, 79913, 79914,
79915, 79916, 79917, 79918, 79919, 79920,
79921, 79922, 79923, 79924, 79925, 79926,
79927, 79928, 79929, 79930, 79931, 79932,
79933, 79934, 79935, 79936, 79937, 79938,
79939, 79940, 79941 and 79942 to appropriate the
public waters of an underground source.
______________________________________/

EUREKA COUNTY'S SECOND LIST OF WITNESSES AND EXHIBITS

EUREKA COUNTY, by and through its attorneys, ALLISON, MacKENZIE, PAVLAKIS, WRIGHT & FAGAN, LTD., in accordance with the State Engineer's Notice of Hearing, dated September 21, 2010, provides its second list of hearing witnesses and exhibits.

EUREKA COUNTY may call any or all of the witnesses and exhibits listed in its initial list served October 22, 2010 and may call any or all of the additional witnesses and utilize any or all of the following additional exhibits in this proceeding:

A. List of Additional Witnesses:

1. John Colby
HC 62
Box 62311
Eureka, NV 89316

Mr. Colby is the owner of land and water rights in Kobeh Valley. Mr. Colby's water rights will be impacted by the mine's pumping based upon the 5 foot drawdown contour line provided by

ALLISON, MacKENZIE, PAVLA RIGHT & FAGAN, LTD.
402 North Division Street, P. O. B 5, Carson City, NV 89702
Telephone: (775) 687-0202 Fax: (775) 882-7918
E-Mail Address: law@allisonmackenzie.com

EUREKA COUNTY in its rebuttal exhibits. Mr. Colby will testify regarding his water rights, and management, monitoring and mitigation.

EUREKA COUNTY reserves the right to call additional witnesses as may be identified resulting from the testimony or exhibits disclosed by the Applicant and rebuttal or impeaching witnesses as may be required at the hearing.

B. List of Additional Exhibits:

501. Walker & Associates, November 23, 2010, Technical Memorandum, Evaluation of Continued Evapotranspiration After Proposed Water Right Transfers From Applications 76744, 76989 and 76990, Prepared for Eureka County Board of Commissioners.

502. Dale C. Bugenig, Consulting Hydrogeologist, LLC, November 24, 2010, Technical Memorandum, Review of Hydrogeology and Numerical Flow Modeling Mt. Hope Project, Eureka County, Nevada, Prepared for Board of Eureka County Commissioners.

503. Lahontan GeoScience, Inc., November 24, 2010, Technical Memorandum, Review of September 2010 Revised Report of the Hydrogeology and Numerical Modeling for the Mt. Hope Project, Prepared for Eureka County Board of Commissioners.

504. PowerPoint Presentation of Walker & Associates.

505. PowerPoint Presentation of Dale C. Bugenig, Consulting Hydrogeologist, LLC.

506. PowerPoint Presentation of Lahontan GeoScience, Inc.

507. Jake Tibbitts, Memorandum dated November 29, 2010 regarding Mount Hope Mine Project Water Resources Monitoring Plan.

508. Copy of Eureka County's Protest to Applications 72695, 72696, 72697, 72698, 73545, 73546, 73547, 73548, 73549, 73550, 73551 and 73552.

509. Copy of Eureka County's Protest to Applications 75988, 75989, 75990, 75991, 75992, 75993, 75994, 75995, 75996, 75997, 75998, 75999, 76000, 76001, 76002, 76003, 76004, 76005, 76006, 76007, 76008 and 76009.

510. Copy of Eureka County's Amended Protest to Applications 76005, 76006, 76007, 76008 and 76009.

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E-Mail Address: law@allisonmackenzie.com

511. Copy of Eureka County's Protest to Applications 76483, 76484, 76485 and 76486.

512. Copy of Eureka County's Protest to Applications 76744, 76745 and 76746.

513. Copy of Eureka County's Protest to Applications 76802, 76803, 76804 and 76805.

514. Copy of Eureka County's Protest to Applications 76989 and 76990.

515. Copy of Eureka County's Protest to Applications77171, 77174, 77175, 77525, 77526 and 77527.

516. Copy of Eureka County's Protest to Application 77553.

517. Copy of Eureka County's Protest to Application 78424.

518. Copy of Eureka County's Protest to Applications 79911, 79912, 79913, 79914, 79915, 79916, 79917, 79918, 79919, 79920, 79921, 79922, 79923, 79924, 79925, 79926, 79927, 79928, 79929, 79930, 79931, 79932, 79933, 79934, 79935, 79936, 79937, 79938, 79939, 79940, 79941 and 79942.

519. Mt. Hope Water Brochure.

520. General Moly Mt. Hope Tour, October 18, 2010.

521. PowerPoint Presentation of Rex Massey.

522. State Engineer's Order 1169.

523. Permit No. 57527.

524. Permit No. 78629.

525. Map of Buckingham Land and Water Rights.

526. Map of Etcheverry Family Limited Partnership Land and Water Rights.

527. Map of MW Cattle Co. Land and Water Rights.

528. Map of Gary Garaventa Land and Water Rights.

529. Map of Eureka Livestock Co. Land and Water Rights.

530. Map of Federal Reserved Water Rights - Stockwater and Domestic.

531. Future Mining Growth and Development in Kobeh Valley.

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Telephone: (775) 687-0202 Fax: (775) 882-7918
E-Mail Address: law@allisonmackenzie.com

532. United States Securities and Exchange Commission, Form 10-Q, Quarterly Report Under section 13 or 15(d) of the Securities Exchange Act of 1934 for the quarterly period ended September 30, 2010 for General Moly, Inc. Commission File No. 001-32986.

EUREKA COUNTY reserves the right to introduce records from the State Engineer's files and records and additional exhibits as may be identified resulting from the testimony or exhibits disclosed by the Applicant and any exhibits to be used for impeachment or rebuttal purposes as may be required at the hearing.

DATED this 29th day of November, 2010.

ALLISON, MacKENZIE, PAVLAKIS,
WRIGHT & FAGAN, LTD.
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Carson City, Nevada 89702

By: [signature]
KAREN A. PETERSON, ESQ.
Attorneys for EUREKA COUNTY

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CERTIFICATE OF SERVICE

I hereby certify that I am an employee of **ALLISON, MacKENZIE, PAVLAKIS, WRIGHT & FAGAN, LTD.**, Attorneys at Law, and on this date, I caused to be delivered the foregoing document(s) as follows:

Via Hand-Delivery to:

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Reno, Nevada 89501

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Reno, Nevada 89509

Tim Wilson, P.E., Hearings Officer
Division of Water Resources
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Via Email and First Class Mail with permission from the recipient to:

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Gene P. Etcheverry
Lander County
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DATED this 29th day of November, 2010.

NANCY FONTENOT

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W Walker & Associates

661 Genoa Lane, Minden, Nevada 89423

EVALUATION OF CONTINUED EVAPOTRANSPIRATION AFTER PROPOSED WATER RIGHT TRANSFERS FROM APPLICATIONS 76744, 76989 AND 76990 TECHNICAL MEMORANDUM

Prepared For: **Eureka County Board of Commissioners**

Prepared By: **Steve Walker (Walker & Associates)**

Reviewed By: **Carol Oberholtzer (Lahontan GeoScience, Inc.) and Dale C. Bugenig (Consulting Hydrogeologist, LLC)**

Dated: **November 23, 2010**

Introduction:

Walker & Associates has been retained by Eureka County as part of a technical team to evaluate the impacts of the proposed pumping of 11,300 acre feet of ground-water annually from the Kobeh Valley hydrographic basin as the main water supply for the proposed Mount Hope molybdenum mine. A portion of the proposed mine's water supply would come from the approval by the State Engineer of applications to change the manner of use and place of use of existing agricultural water rights within the Kobeh Valley hydrographic basin to mining and milling water rights. Three (3) of those applications – 76744, 76989 and 76990 – would transfer agricultural water rights from areas of existing groundwater discharge (phreatophytic areas). These areas are commonly referred to as Bean Flat (Application 76744) and Bartine Ranch (Applications 76989, 76990) and currently support meadow vegetation due to groundwater occurring at or near the land surface. Some water spreading at the Bartine Ranch does occur as a result of two artesian wells located on the property.[1]

Using the groundwater model developed by the consultants for the Mount Hope project, an analysis was conducted to determine if continued evapo-transpiration would occur at these areas if the water rights were transferred and pumped for mining and milling purposes. Eureka County's contention is that if evapo-transpiration is still occurring from these areas where the water rights had been transferred (per the groundwater model), then that water should be discounted from the consumptive use duty before the water is transferred to maintain recharge/discharge equilibrium in the hydrographic basin.

[1] A report prepared by Walker & Associates specific to the beneficial use of the water for these areas and other applications associated with the mine project is as part of the evaluation conducted by Walker & Associates and was included in the initial document exchange on October 22, 2010.

Phone: (775) 782-4469 stevewalker@gbis.com Fax: (775) 782-4833

Discussion

To determine the amount of draw down of the groundwater in the Bean Flat and Bartine Ranch areas, Carol Oberholtzer, Lahontan GeoScience, Inc. and part of the Eureka County consultant team, used the groundwater model provided by the General Moly consultants - Hydrogeology and Numerical Modeling, Mt. Hope Project, Eureka County, Nevada (July 2010, revised September 2010) - to develop more refined maps depicting the change in groundwater elevation using two scenarios listed in that report as:

> The Cumulative Action Scenario which consists of continued agricultural pumping, plus construction and operation of the Mt. Hope mine project, including Kobeh Valley Central Well Field (KVCWF) pumping, construction water supply pumping, and open pit dewatering; and
>
> The Proposed Action Alternative which exclusively examines the effect of the Mt. Hope project, which results from KVCWF pumping, construction water supply and open pit de-watering.[2]

Using the model's capability to estimate change in ground-water levels under different pumping scenarios, one can determine how much drawdown would generally occur in the phreatophytic discharge areas where the Bartine Ranch and Bean Flat are located. To refine this analysis, a groundwater level drawdown contour of 5 feet was generated from the model to better demonstrate the effect of pumping to the Kobeh Valley phreatophytic areas. (Figure 1) From this information one can estimate the amount of evapo-transpiration that will occur on the properties if the water rights were transferred and pumped in a different location within the hydrographic basin. If the pumping scenario does not induce a water table drawdown in the area, one can simply assign the existing discharge value associated with the assigned evapo-transpiration (ET) zone. In areas within the water-righted property where drawdown does occur but is still within the 40 foot extinction depths of the surrounding phreatophytic communities, a plant community succession would occur over time. Meadow areas would be re-occupied by phreatophytic shrubs – grease wood and rabbit brush – and consumptive use of groundwater would be decreased. The effect on the change of evapo-transpiration can be captured by reassigning a different ET zone to those areas associated with the properties where groundwater has dropped below 10 feet from land surface but less than 40 feet. If the water right is moved at a consumptive use duty of 2.7 acft/acre[3] and yet consumptive use is still occurring, then that volume of consumptive use by the non-effected phreatophytes needs to be discounted from the water right transfer. If pumping induced drawdown eliminated phreatophytic discharge, the discount would not apply.

---

[2] The No Action Alternative would have no effect on the phreatophytic discharge from the properties in question so it was not considered.

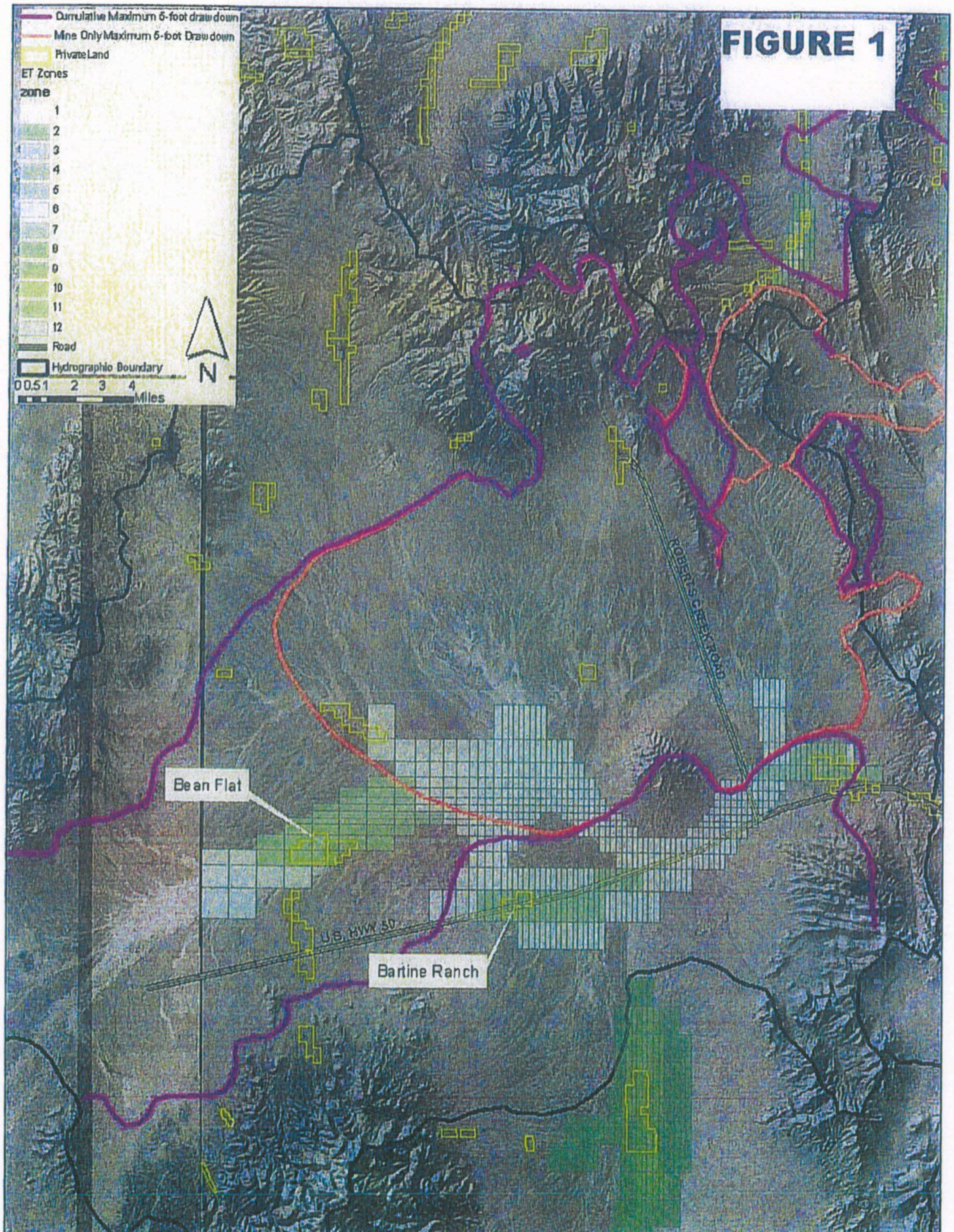
[3] "*Evapotranspiration and Net Irrigation Water Requirements for Nevada*"; J. L. Huntington and R. G. Allen.

Figure 1 on the following page depicts the effect on groundwater elevation within Kobeh Valley under both the cumulative impact and mine-only pumping scenarios. Furthermore, the figure identifies the existing phreatophytic discharge areas and the properties associated with the water right applications. The contour depicting the mine only pumping scenario demonstrates that the water level decline would be minimal (less than 5 feet) on the two properties. Both areas occur in phreatophytic Zone 7 (10 foot extinction depth with maximum ET at 0.012 ft/day) and current water levels in these areas are within 5 feet of land surface[4]. The mine only scenario does affect the Grub Flat parcel and the associated stock water right for that allotment.

The contour depicting the drawdown under the cumulative pumping scenario does impact both properties. To specifically analyze and estimate the effect of this scenario, Walker & Associates, with the assistance of Carol Oberholtzer (Lahontan GeoScience, Inc.) and Jake Tibbitts, Natural Resources Manager for Eureka County, developed Figures 2 and 3 and Tables 1 and 2 to demonstrate that evapo-transpiration will continue to occur on both parcels under the maximum pumping of the basin and one can estimate how much evapo-transpiration can occur. The drawdown - difference from the estimated groundwater level in 1955 to the groundwater level in 2055 after 44 years of pumping at the mine and the Bob Cat Ranch - is calculated from the computer model for the year 2055, transient base case. The model, per Carol Oberholtzer, shows no evapo-transpiration occurring in the specific model cells where the water-righted lands occur. Evapo-transpiration (ET) is occurring in the model in the adjacent phreatophytic areas where the extinction depth is 40 feet. The extinction depth of the ET area within the model cells where the parcels are located is 10 feet. Although the model does not recognize ET at these sites, in reality ET is occurring on these model cells and can be estimated based on water measurements from the State Engineer Cropping Reports and the existing vegetation on these sites. From this evidence, Walker & Associates estimates the ground-water elevation at 5 feet below land surface at both properties and used the ET rate assigned to the site by the regional model to develop Tables 1 and 2. The data used from the model - the drawdown of the groundwater from 1955 through 2055 under the cumulative pumping scenario - was applied to an estimate of the existing groundwater level at both properties to estimate the affect on the rate of ET under the cumulative pumping scenario.

The mine-only pumping scenario showed that the groundwater level drawdown had little or no effect on either area and was not analyzed. As previously mentioned one could simply use the existing evapo-transpiration occurring from these areas to discount the duty of the proposed water right transfer.

[4] Assessment of Beneficial Use on Certain Parcels Associated with Water Rights Transfers in Kobeh Valley Hydrographic Basin referenced in footnote 1.



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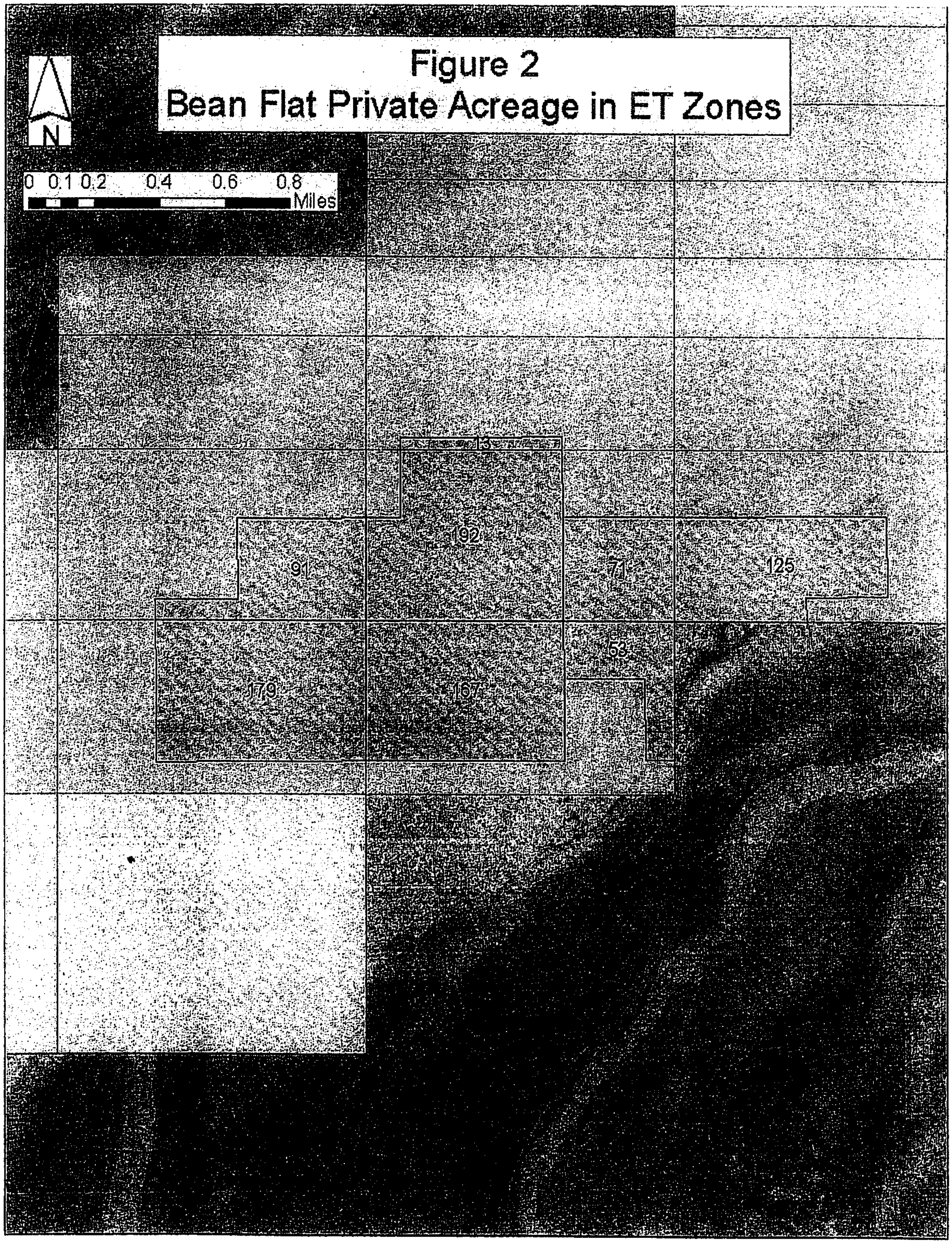

Figure 2
Bean Flat Private Acreage in ET Zones

Bean Flat – Table 1

R(1)	C(1)	WS – 1955(2) (feet)	WS – 2055(3) (feet)	Draw-down (feet)	Assumed Depth to Water 2010 (4) (feet)	Depth to water 2055 (5) (feet)	ET Zone ft/day (6)	ET ft/yr	Acres in cell (Fig 2)	acft/yr ET (7)
114	21	6148	6138	9.9	5	14.9	0.00114	0.42	91	46
114	22	6140	6131	9.2	5	14.2	0.00116	0.42	263	110
114	23	6132	6124	8.5	5	13.5	0.00121	0.44	125	55
113	22	6135	6126	8.8	5	13.8	0.00119	0.43	13	6
115	21	6150	6139	11.1	5	16.1	0.00107	0.39	179	70
115	22	6141	6132	9	5	14.0	0.00119	0.43	219	94
									Total	**381**

(1) Regional Groundwater Model Row and Column Numbers

(2) Water Surface elevation from Model at Steady State Condition - 1955

(3) Water Surface elevation from Model cumulative pumping scenario – 2055

(4) Currently the model shows no ET occurring in this area because land surface estimate is more than 10 feet above the steady state water surface estimate yet the area is within ET zone 7 - with a 0.012 ft/day rate and an extinction depth of 10 feet. Per cropping reports the groundwater at 3.2 to 4.2 feet.

(5) Draw down plus assumed 2010 depth to water surface

(6) If drawdown is more than 10 ft then ET zone 6 is applied; if less than 10 feet then ET zone 7 applies. Rate per day determined through linear regression graphs.

(7) Estimated ET (acft/yr) remaining at within the parcel after cumulative pumping for 44 years

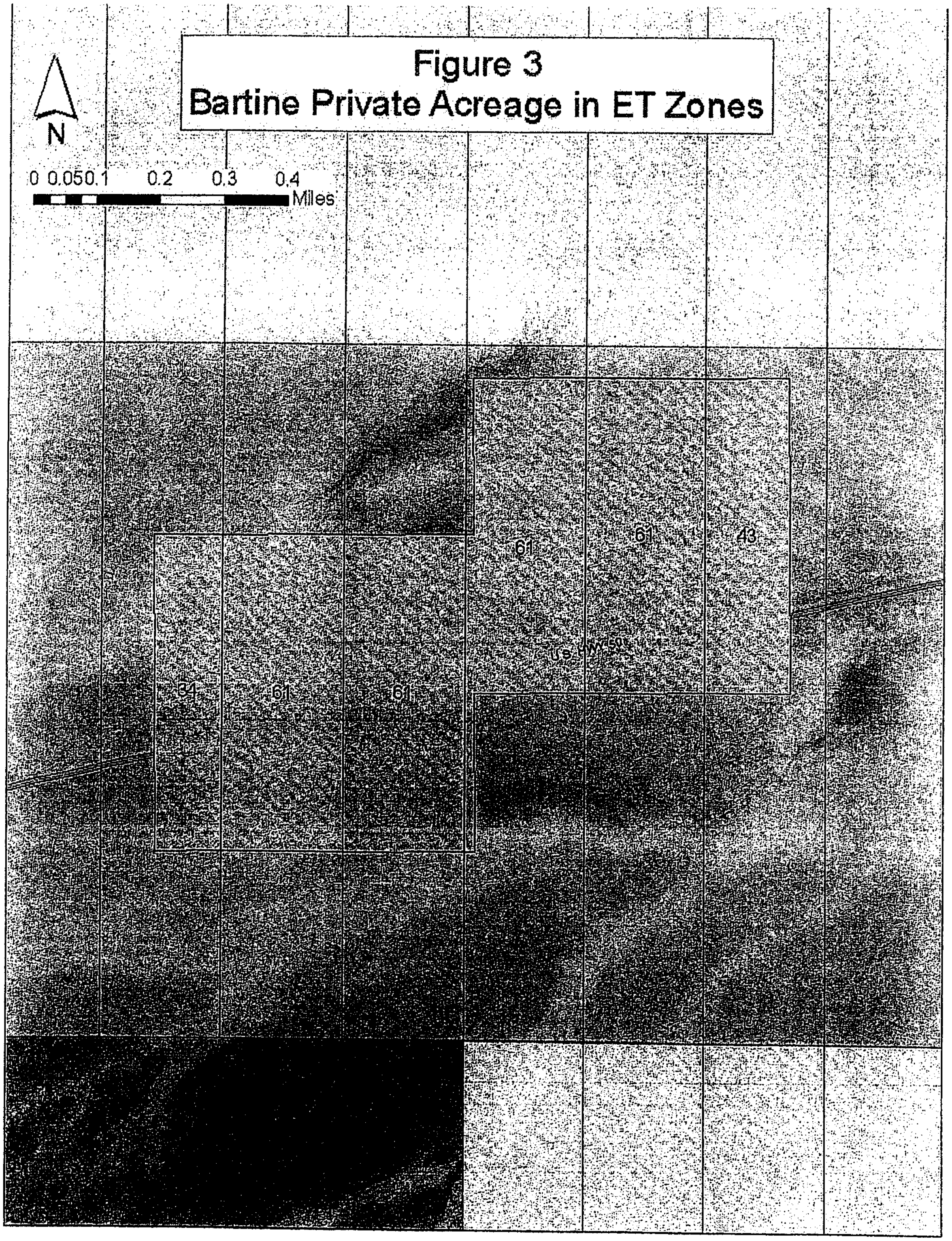

Figure 3
Bartine Private Acreage in ET Zones

003265

JA4677

Bartine Ranch – Table 2

R[1]	C[1]	WS – 1955[2] (feet)	WS – 2055[3] (feet)	Draw-down (feet)	Assumed Depth to Water 2010 [4] (feet)	Depth to water 2055 [5] (feet)	ET Zone ft/day [6]	ET ft/yr	Acres in cell (Fig 2)	acft/yr ET [7]
117	34	6085	6081	3.0	5	8.0	0.002	0.73	34	25
117	35	6084	6081	3.1	5	8.1	0.00215	0.78	61	48
117	36	6082	6079	2.9	5	7.9	0.0023	0.84	61	51
117	37	6081	6078	2.9	5	7.9	0.0023	0.84	61	51
117	38	6080	6077	2.8	5	7.8	0.0025	0.91	61	56
117[8]	39	6079	6077	2.5	5	7.5	0.0027	0.98	43	42
									Total	273

(1) Regional Groundwater Model Row and Column Numbers

(2) Water Surface elevation from Model at Steady State Condition - 1955

(3) Water Surface elevation from Model cumulative pumping scenario – 2055

(4) Currently the model shows no ET occurring in this area because land surface estimate is more than 10 feet above the steady state water surface estimate yet the area is within ET zone 7 – with a 0.012 ft/day rate and an extinction depth of 10 feet. Per cropping reports the depth to groundwater is not measured due to artesian flow at wells.

(5) Draw down plus assumed 2010 depth to water surface

(6) If drawdown is more than 10 ft then ET zone 6 is applied; if less than 10 feet then ET zone 7 applies. Rate per day determined through linear regression graphs.

(7) Estimated ET (acft/yr) remaining at within the parcel after cumulative pumping for 44 years

(8) Estimated - lacked data from cell

Results:

The analysis shows evapo-transpiration will continue to occur at these discharge areas under all pumping alternatives. Under the most likely scenario - mine-only pumping - the evapo-transpiration would be much greater at these private properties than depicted in Table 1 and 2. For example, if no draw down occurs at the Bartine Ranch, the evapo-transpiration rate per day would be estimated at 0.006 ft/day or 2.19 acft/yr/acre. (Assumes a groundwater level of 5 feet below surface.) Moving the place of use of the water right does not move the point of groundwater discharge - it creates two points of ground-water discharge. The volume of water consumed at these two points should not exceed the consumptive use duty of the original water right.

The three reports entitled:

Walker & Associates Report, Assessment of Beneficial Use on Certain Parcels Associated With Water Right Transfers in Kobeh Valley Hydrographic Basin, updated to October 15, 2010, with attachments;

Walker & Associates Memorandum, Updated Estimates of Consumptive Use of Irrigated Crops in Eureka County dated October 15, 2010; and

Walker & Associates, November 19, 2010, Technical Memorandum, Evaluation of Continued Evapotranspiration After Proposed Water Right Transfers from Applications 76744, 76989 and 76990

have been prepared by the undersigned and are submitted to the Nevada State Engineer in support of Eureka County's protests to pending water right applications 72695, et al., to appropriate the public waters of an underground source, filed by Kobeh Valley Ranch, LLC for the Mount Hope Mine Project, Eureka County, Nevada.

WALKER & ASSOCIATES

Dated: November 23, 2010

By: Steve Walker
STEVE WALKER, Principal

**Dale C. Bugenig,
Consulting Hydrogeologist, LLC**

Review of Hydrogeology and Numerical Flow Modeling Mt. Hope Project, Eureka County, Nevada

Technical Memorandum

Prepared for: Board of Eureka County Commissioners

Prepared by: Dale Bugenig

Reviewed by: Jake Tibbitts, Natural Resource Manager

Date: November 24, 2010

Dale C. Bugenig

INTRODUCTION

The Board of Eureka County Commissioners engaged Walker and Associates, Lahontan GeoScience, Inc. and Dale C. Bugenig, Consulting Hydrogeologist, LLC. to review the results of investigations into the potential changes in the groundwater regime arising from Eureka Moly LLC's proposed Mount Hope Project. In particular, the review addresses the project's intent to appropriate and consume 11,300 acre-feet of groundwater yearly for 44 years primarily from Kobeh Valley in Eureka County. The methods and results of the investigations and a numerical groundwater flow model of the study area are summarized in *Hydrogeology and Numerical Flow Modeling Mt. Hope Project, Eureka County, Nevada* by Montgomery and Associates, Interflow Hydrology, Inc, and Barranca Group, LLC (Montgomery, *et al.,* July 2010, revised September 2010). Supporting information and data are provided in a plethora of technical reports which were also reviewed. As was the case in 2008 for the previous hearing before the State Engineer, we want it to be patently clear that the County's consultant team was not engaged in an effort to stop the Mt Hope Project as some individuals assert. Our charge, which is consistent with Eureka County's goals, is, and has been from the outset of our involvement in this matter two years ago, to help the County become aware of the potential changes in the water-resources regime and the environment arising from a project that proposes to consume the vast majority of the renewable groundwater resources in Kobeh Valley. Part of our job involved critically reviewing the mine's consultants' groundwater model, including providing constructive criticism and identifying weakness, where appropriate, in order to enhance the use of the model to predict impacts on water resources.

Table 8: Modal analyses of representative samples of quartz-monzonite rocks.

Sample number:	232	235	236	240	243	Average
Quartz	34.8	36.4	31.2	30.0	29.4	32.5
Plagioclase	32.2	38.2	39.0	36.4	32.0	34.5
Composition	41	38	36	37	35	37
Orthoclase	23.8	16.2	21.0	26.8	30.2	25.5
Muscovite	8.4	8.0	8.2	5.2	6.0	6.3
Biotite	0.6	0.6	0.4	1.0	1.0	0.5
Opaques	0.2	0.6	0.2	tr.	1.0	0.1
Zircon	tr.	tr.	tr.	0.2	--	tr.
Tourmaline	--	tr.	--	tr.	--	--
Apatite	--	tr.	--	--	tr.	--
Hematite	tr.	--	--	tr.	0.4	tr.
Sericite Pseudomorphs	--	--	tr.	0.4	--	--
Calcite	--	--	--	--	--	--
Epidote	--	--	--	--	--	--
Chlorite	--	--	--	--	--	--
Groundmass	--	--	--	--	--	--
Grain size	0.8-0.2	1.0-0.02	0.4-0.01	0.7-0.03	0.8-0.03	0.7-0.03

Description of samples:

232 - fine-grained allotriomorphic quartz-monzonite
235 - fine-grained porphyritic-allotriomorphic granodiorite
236 - fine-grained allotriomorphic quartz-monzonite
240 - fine-grained allotriomorphic quartz-monzonite
243 - fine-grained allotriomorphic quartz-monzonite
average - fine-grained allotriomorphic quartz-monzonite

occasionally and resemble spherulites. Parallel alignment of laths occurs infrequently and may be related to flowage. Granophyre is present locally.

Most of the plagioclase crystals show some sericitic alteration. A few are unaltered; and a few, 0.2 percent, are completely altered to sericite pseudomorphs.

Quartz - Quartz comprises from 29.4 to 36.8 percent of the rock, and averages 32.5 percent. It ranges in size from 0.02 to 0.6 mm in length, and occurs dominantly as anhedral, non-poikilitic, embayed grains that average 0.12 mm in length. Poikilitic inclusions in the quartz grains consist primarily of anhedral to euhedral plagioclase laths about 0.03 mm long; rare anhedral to euhedral orthoclase; and very rare opaque minerals. Circular arrangements of inclusions occur, but are rare and generally confined to the larger quartz grains. Locally, quartz grains are clustered.

Orthoclase - Orthoclase represents 19.0 to 43.8 percent of the quartz-monzonite, and averages 25.5 percent. Anhedral grains are dominant, and average less than 0.1 mm in length. Rarely, however, some grains occur as 0.4 mm long, phenocrysts. Inclusions are rare and are commonly small plagioclase laths and less commonly quartz. Orthoclase occurs as overgrowths on plagioclase and interstitially between plagioclase crystals. Orthoclase appears to be untwinned, and occasionally replaced by quartz. Sericitic alteration is similar to that displayed by plagioclase.

Muscovite - The quartz-monzonite contains both primary and secondary muscovite, which together constitute between 0.6 and 9.8 percent of the rock, and average 6.3 percent. Muscovite is generally 0.1 mm long, but may occasionally exceed a length of 0.3 mm. Secondary muscovite often contains small grains of unreplaced biotite. Primary muscovite is occasionally poikilitic and/or may be molded around quartz grains. Kink banding is non-deformational and occurs only locally.

Accessory Minerals - Reddish brown biotite comprises from a trace to 2.0 percent and averages 0.5 percent of the rock. Grains are anhedral to euhedral, averaging about 0.1 mm in length. Large grains may reach a length of 0.35 mm. Biotite occasionally poikilitically incloses quartz, orthoclase, plagioclase, and opaque minerals. Non-deformational, kink banding is present.

Opaque minerals range from a trace to 1.0 percent, with an average of 0.1 percent. They frequently occur as inclusions in the micas as small, 0.01 to 0.1 mm long, blebs or stringlets parallel to the folia. Magnetite is primary and occurs as small needles or blebs in quartz. Secondary opaque minerals occur in veinlets and the micas. Hematite is a rare alteration product of the magnetite.

Tourmaline, schorlite, occurs only in trace amounts as small, semi-rounded grains less than 0.05 mm long. Occasionally the tourmaline grains grow on orthoclase and around quartz. White halos may occur around the tourmaline grains but are difficult to identify.

Apatite and zircon are very rare. The apatite occurs as small, 0.01 mm long, rounded grains in quartz. Zircon occurs as doubly terminated crystals about 0.02 mm long, primarily in quartz grains.

Secondary calcite is present as overgrowths on some minerals.

Microporphyritic-Hypidiomorphic Facies

This facies is present as sills and at the margins of the pluton. Flow structures are often present in this phase. The contact between this phase and the coarser quartz-monzonite phases is gradational.

Macroscopic Description

Rocks of this facies are greenish-gray, olive gray, and medium bluish-gray. They may weather to light gray or light bluish-gray, but are more commonly moderate orange pink to moderate reddish-brown. These are often stained by manganese-oxide or desert varnish. The rocks are aphanitic, sparsely porphyritic, dense, and hard. Hand lens analysis indicates that the porphyritic minerals are quartz and muscovite. In hand specimen the rock is best termed a felsite.

The contact between this phase of the pluton and the country rock is very sharp, and marked by a change from the lighter color of the pluton to the dark gray or brown of the country rock. No metamorphism is present.

Microscopic Description

Thin section analyses indicates a microporphyritic-hypidiomorphic texture; the average grain size is 0.1 mm or less in length, and that the rock consists of plagioclase, orthoclase, quartz, a very fine-grained groundmass, accessory biotite, opaque minerals, zircon, and secondary calcite. Point count analyses indicates the rock is probably a quartz-monzonite (table 9). Minor stoping of the country rock occurs (fig. 16), but is confined to the outermost 5 cm of the contact zone. Minor flow structures are also present at or near the contact zone.

Mineralogy

Plagioclase - Plagioclase comprises at least 27.2 percent of this rock. Composition of the plagioclase is An_{33} to An_{38}, andesine. Grains range in size from less than 0.01 mm long in the groundmass, to phenocrysts over 1.0 mm in length. Albite twinning is dominant; Carlsbad-albite twinning is present locally. Untwinned crystals are common. Zoning of plagioclase is rare.

Phenocrysts are subhedral to euhedral and average about 0.3 mm in length. Corrosion by impinging crystals is rare. Synneusis twinning is absent. Joined crystals do occur and commonly exhibit an irregular contact, which may contain quartz grains and opaque minerals. Inclusions in phenocrysts consist of quartz and opaque minerals. These inclusions, however, are rare and are always confined to the outer margins of the phenocryst.

The groundmass plagioclase occurs as andesine laths which are generally subhedral to euhedral, average about 0.1 mm in length, and show little if any corrosion by impinging crystals. Smaller laths are very common in the groundmass.

Most of the plagioclase crystals show some sericitic alteration. Generally the most intense alteration is at the core, however, a few are completely altered.

Altered and unaltered spherulites, also called variolites, occur sporadically throughout most of this phase. The spherulites consist of radiating and concentrically arranged plagioclase needles that average between 0.1 and 0.15 mm in diameter. Often these radial aggregates are surrounded by a thin, 0.01 mm, rim of alkali-feldspar, and contain small grains of quartz(?) at or near their center. Between crossed-polarizers the plagioclase of the spherulites show dark crosses which resemble a uniaxial interference figure. According to Johannsen (1932) "the dark bars are parallel to the vibration planes of the nichols when the extinction angles of the individual minerals are zero. As the stage is rotated, successive needles come into parallel position, consequently the cross remains parallel to the cross-hairs." Williams and others (1954) indicate that spherulitic texture reflects rapid crystallization of a viscous magma.

Granophyric intergrowths of plagioclase and quartz are present locally.

Table 9: Modal analyses of representative samples of quartz-monzonite rocks.

Sample number:	12	12B	113	184	197B	6-2-81
Quartz	—	—	24.0	—	24.8	24.4
Plagioclase	—	—	27.2	—	29.0	31.4
Composition	36	37	--	38	--	38
Orthoclase	29.4	—	—	—	34.2	20.2
Muscovite	—	—	6.4	—	—	—
Biotite	—	—	0.4	0.6	--	—
Opaques	0.6	—	tr.	0.2	--	tr.
Zircon	tr.	--	tr.	--	tr.	tr.
Tourmaline	--	--	--	--	--	--
Apatite	--	--	--	--	--	--
Hematite	tr.	--	--	tr.	--	--
Sericite Pseudomorphs	--	tr.	--	--	--	tr.
Calcite	1.2	--	--	--	--	--
Epidote	--	--	--	--	--	--
Chlorite	--	--	--	--	--	--
Groundmass	64.0	95.0	42.0	78.0	12.0	20.0
Grain size	1.5- -0.01	2.0- -0.01	0.6- -0.01	0.3- 0.01	0.3- -0.01	0.3- -0.01

Description of Samples:

12 - cryptocrystalline porphyritic-hypidiomorphic quartz-monzonite(?)

12B - cryptocrystalline porphyritic-hypidiomorphic quartz-monzonite(?)

113 - cryptocrystalline porphyritic-hypidiomorphic quartz-monzonite(?)

184 - cryptocrystalline hypidiomorphic quartz-monzonite

197B - cryptocrystalline porphyritic-poikilitic-hypidiomorphic quartz-monzonite

6-2-81 - cryptocrystalline porphyritic-poikilitic-hypidiomorphic quartz-monzonite

<u>Orthoclase</u> - Orthoclase comprises about 30.0 percent of the rock. It occurs generally as anhedral grains in the groundmass and averages 0.05 mm or less in length. A few crystals exceed a length of 0.1 mm. Orthoclase appears to be untwinned, and may locally embay(?) quartz. Sericitic alteration is similar to that displayed by plagioclase.

<u>Quartz</u> - Quartz comprises at least 24.8 percent of the rock, and occurs as subhedral to euhedral grains (figs. 17, 18) that range in length from 0.02 to 0.6 mm and averages 0.1 mm in length. Poikilitic quartz is present in this rock facies; it is rare at or near the margin, increasing in abundance away from the margin of the pluton. Inclusions are dominantly subhedral to euhedral plagioclase laths, about 0.05 mm long; anhedral to euhedral orthoclase is less common; opaque minerals are rare.

<u>Groundmass</u> - The groundmass comprises between 42.0 and 78.0 percent of the rock, and is composed of crystals that are less than 0.05 mm long which consist of feldspar (dominantly plagioclase?), quartz, sericite, and opaque minerals.

<u>Accessory Minerals</u> - Brown biotite comprises a trace to 0.6 percent of the rock, is generally euhedral, and reaches over 0.1 mm in length. It commonly occurs as a network of individual veinlets which show non-deformational kink banding. Biotite is altered to opaque minerals, which are oriented parallel to its folia.

Opaque minerals comprise 0.0 to 0.2 percent of the rock.

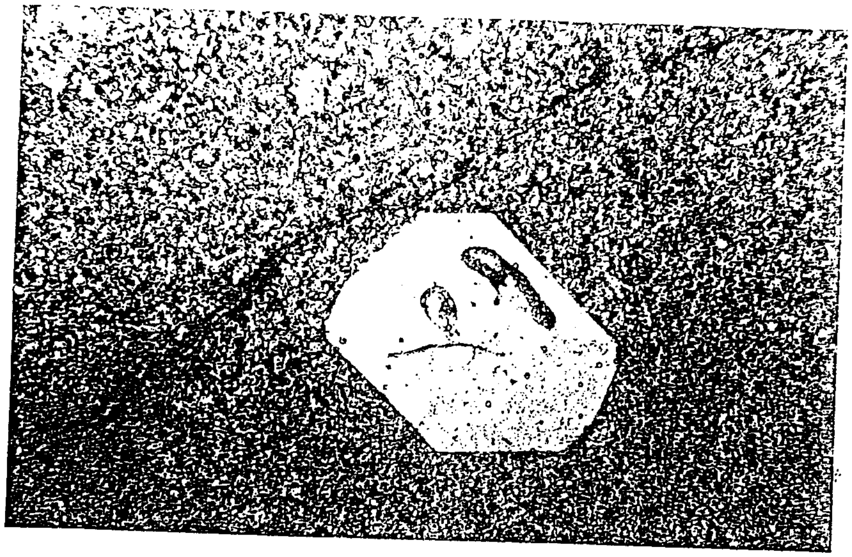

Fig. 17. Photomicrograph of a euhedral quartz grain in the cryptocrystalline phase of the microporphyritic-hypidiomorphic facies (#12B). Low power (25x).

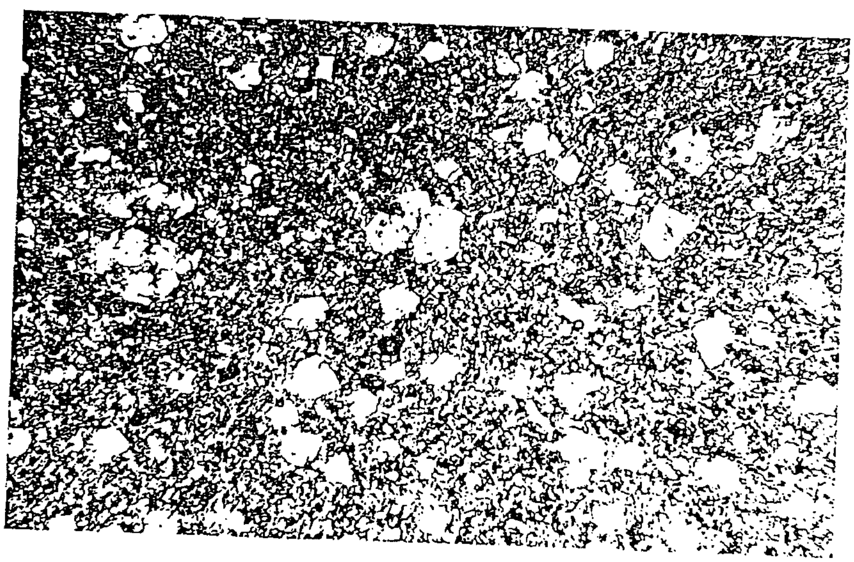

Fig. 18. Photomicrograph of the microporphyritic-hypidiomorphic facies grading into the microporphyritic-poikilitic-hypidiomorphic facies. Quartz (white) includes subhedral to euhedral plagioclase laths (#197B). Low power (25x).

Magnetite is primary and generally confined to quartz grains as small, 0.05 mm long grains. Secondary opaque minerals occur in veinlets and the micas. Hematite is rare, and is an alteration product of the magnetite.

Zircon is present in trace amounts as doubly terminated needles, 0.05 to 0.1 mm long, in quartz grains.

Secondary calcite is rare and occurs primarily along small veinlets in association with manganese-oxide staining, and as an alteration product of plagioclase.

Microporphyritic-Poikilitic-Hypidiomorphic Facies

This facies is restricted to the western half of the mountain, where it is present near the outer border of the pluton. The contact between this phase and adjacent phases is gradational.

Macroscopic Description

Rocks of this facies are white, grayish-white, and slate blue. They may weather greenish-white or orange brown. Locally, on exposed surfaces, the rocks are stained by manganese-oxide and desert varnish. These rocks are felsitic, dense, and very hard. Hand lens analysis indicates they consist of muscovite, quartz, and feldspar. The muscovite is present as small, scattered, silver phenocrysts, which are surrounded by a white halo. Quartz occurs as easily recognizable phenocrysts. Feldspar is difficult to identify and confined to the groundmass(?). In hand specimen, this rock is best termed an aplite.

Microscopic Description

Thin section examination indicates a microporphyritic-poikilitic-hypidiomorphic texture; the average grain size is between 0.1 and 0.2 mm; and that the rock consists of plagioclase, orthoclase, quartz, indeterminate groundmass, accessory biotite, opaque minerals, and zircon. Point count analyses indicate the rock is probably a quartz-monzonite (table 9).

Mineralogy

Plagioclase - Plagioclase comprises at least 29.0 percent of the rock. Composition of the plagioclase is An_{38}, andesine. Crystals range in length from less than 0.03 to over 0.3 mm. Albite twinning is dominant; Carlsbad-albite twinning is present locally. Untwinned crystals are common. Zoning is very rare. Synneusis twins are absent.

Phenocrysts are dominantly euhedral, and average 0.25 mm in length. Inclusions, corrosion, and joining with other phenocrysts are very rare.

Laths are generally euhedral except where corroded by impinging laths and the groundmass. The average length of a lath is 0.07 mm, except in the groundmass where it is 0.03 mm or less.

Sericitic alteration is common especially in the cores of plagioclase crystals. A few are completely altered to sericite.

Orthoclase - Orthoclase comprises from 20.0 to over 34.0

percent of the rock, and occurs dominantly as anhedral grains less than 0.1 mm in length. Orthoclase occasionally occurs as overgrowths on plagioclase and interstitially between plagioclase crystals. Orthoclase appears to be untwinned, and is sericitically altered like plagioclase.

Quartz - Quartz comprises over 24.0 percent of the rock, and occurs, generally, as subhedral to euhedral, embayed grains that range in length from 0.01 mm grains in the groundmass to 0.5 mm long phenocrysts. Quartz averages about 0.14 mm in length. Poikilitic quartz is common, and the inclusions consist dominantly of subhedral to euhedral plagioclase laths about 0.07 mm long; less commonly anhedral orthoclase; and rare opaque minerals. Circular arrangements of inclusions occur locally and are generally confined to larger quartz grains.

Groundmass - The groundmass comprises between 12.0 and 20.0 percent of the rock, and is composed of feldspar (dominantly plagioclase?), quartz, sericite, and opaque minerals. The average length of the grains is less than 0.05 mm.

Accessory Minerals - Reddish-brown biotite is present in trace amounts as 0.05 mm long, anhedral grains. It may occur molded around quartz or plagioclase, and is generally a darker brown around the inclosed opaque mineral.

Opaque minerals are present in trace amounts as anhedral grains less than 0.05 mm in length. Primary magnetite is dominant and occurs as inclusions in quartz, biotite(?), and the groundmass.

Zircon comprises a trace amount and generally occurs as small, 0.05 mm long, doubly terminated crystals, primarily in quartz grains. Fluid inclusions are present in some crystals.

Quartz Veins

Milky white to pale olive, green-gray quartz veins are present in the southern and western portions of the pluton. Their average width is about 6.5 mm; and they are usually less than a meter long. Some appear to fill shear zones(?), others clearly are dikes.

In specimen rock, 6-4-81 (table 6), a quartz vein 6.5 mm wide occurs and consists of small and large intergrown milky white quartz crystals. The long axes of smaller crystals are parallel to the vein walls. Undulatory extinction is shown by all the quartz crystals in the vein. Several small muscovite grains are present and are molded around the small quartz crystals. The vein-rock contact is sharp, except where the quartz of the host rock has reacted with vein quartz. Where this occurs, the vein quartz retains the inclusions of the older quartz. Rocks adjacent to the vein are unaltered and maintain their original texture.

In rock 75A, (table 2), a 6.6 mm wide quartz vein is present, which consists of cryptocrystalline and radiating quartz crystals, opaque minerals, and barite(?) (fig. 19). The radiating crystals may attain a length of 0.9 mm, be attached to the vein wall, and grow perpendicular to the wall into the vein. Undulatory extinction is absent. The enclosing rock is a fine-grained porphyritic-poikilitic-allotriomorphic quartz-monzonite. It has been silicified and extensively altered. The average grain size of the quartz is twice that of the quartz in unaltered rocks of this facies. Muscovite, sericitic plagioclase, opaque minerals, biotite, and ziron are present in varying amounts.

Tourmaline

In igneous rocks tourmaline is generally associated with epizonal, silica-rich bodies such as aplites, some granites, and granite pegmatites (Buddington, 1959). According to Black (1971), tourmalization "coincides with the pneumatolitic phase of plutonism" and tourmaline appears to inherit its composition, in part, from the host rock.

Tourmaline is stable over a wide range of P-T conditions (Ethier and Campbell, 1977). However, work by Smith (1949) indicates that "tourmaline has a narrow range of stability with regard to alkalinity." His work also suggests that the occurrence of tourmaline is dependent on the relative amounts of Na_2O and B_2O_3, which indicates that the pH range is probably more important than P-T conditions (Ethier and Campbell, 1977).

Because of its high mobility and vapor pressure, boron tends to be concentrated in late-stage magmatic fluids and/or the vapor phase associated with siliceous magmas (Rankama

Fig. 19. Photomicrograph of a quartz vein. Radiating quartz crystals to right, cryptocrystalline quartz crystals to left. Elongate euhedral barite(?) crystals present left to right, near center (#75A). Low power (25x).

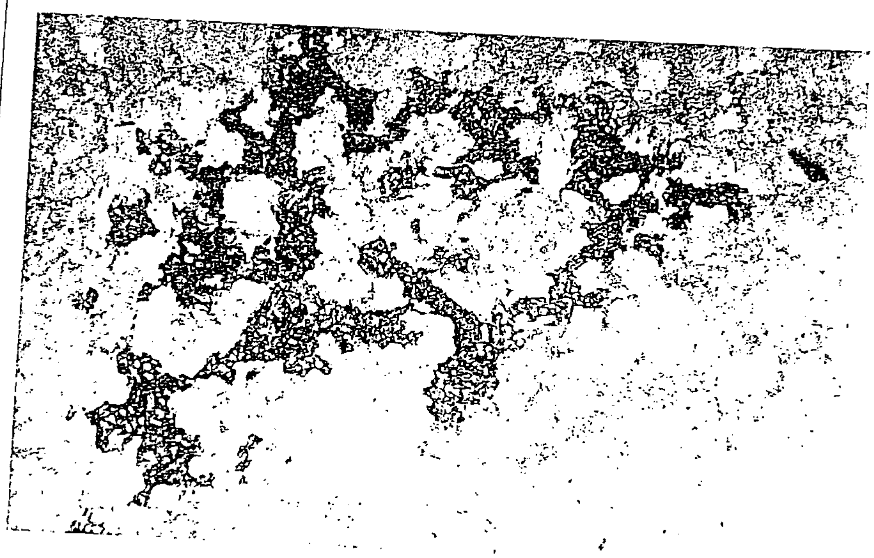

Fig. 20. Photomicrograph of a tourmaline spot along a resealed joint. Quartz is white, plagioclase is gray (#134). Low power (25x).

and Sahama, 1950; Krauskopf, 1967). In his study of the Říčany massif in central Bohemia, Němec (1978) describes two types of tourmaline, a syngenetic tourmaline which crystallized from the magma and a rarer epigenetic tourmaline. The syngenetic tourmaline is mostly fine-grained, automorphic, often concentrically zoned, and formed by the metasomatic replacement of feldspars in the presence of boron and femic components. Deer and others (1963) note during tourmalization that biotite is attacked first to produce a yellow tourmaline, feldspars are secondarily attacked and are replaced by blue to blue-green tourmaline.

The various colors of tourmaline are a function of the transitions of different ions within the mineral. In schorlite the blue color is due to transitions within Fe^{2+} and Fe^{3+}, and possibly Mn^{3+} (Manning, 1969).

At Whistler Mountain, tourmaline occurs as disseminated spots, nodules, and along joints, some of which have been resealed.

Spots

Tourmaline spots (figs. 20, 21) are restricted to the poikilitic- and non-poikilitic-allotriomorphic facies of the quartz-monzonite, where they are scattered irregularly. The spots are spherical, 0.2 to 3.0 mm in diameter, and always surrounded by a spherical white halo. The contact between the halo and the tourmaline core is always sharp. The white halos are virtually devoid of biotite. Muscovite and plagioclase laths decrease in size and abundance towards the center of the spot; occasionally small grains of muscovite are molded around or inclosed by tourmaline. Poikilitic quartz, however, shows a reverse relationship. Orthoclase is rarely present. The center of a spot is comprised primarily of schorlite, an iron-rich tourmaline variety, and quartz. The schorlite is blue, allotriomorphic, and poikilitically incloses subhedral to euhedral plagioclase laths; rarely incloses relict, anhedral orthoclase grains; and very rarely incloses opaque minerals. The feldspars are replaced along grain boundaries and by a network of irregular tourmaline veinlets (figs. 21, 22), which are often interconnected. In the larger spots, greater than 1.0 mm in diameter, the tourmaline grains show a slight, circular arrangement.

Nemec (1975) studied similar tourmaline spots in aplitic granites of eastern Europe: " . . . tourmaline spots are scattered irregularly. Their sizes range from one to twenty centimeters. They are spherical, . . . light halos around the tourmaline spots are always present. The halos also are spherical, having sizes proportionate to their tourmaline cores. Their boundaries with the tourmaline cores are always sharp.

The tourmaline spots are essentially quartz-tourmaline mixtures. Under the microscope, tourmaline is brown, brownish green or blue, and allotriomorphic. It replaces selectively potassium feldspar, less intensively plagioclase.

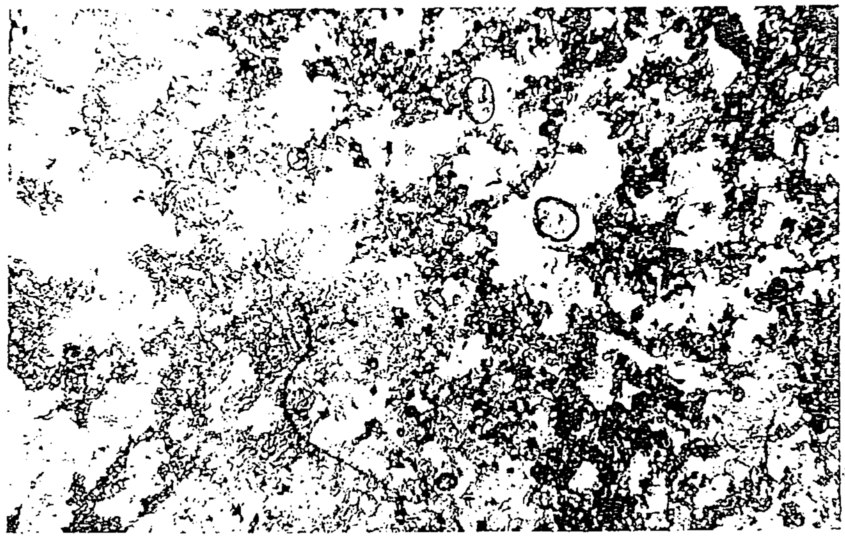

Fig. 21. Photomicrograph of a tourmaline spot showing the contact between tourmaline and quartz, left, and unaltered host rock, right (#134). Low power (25x).

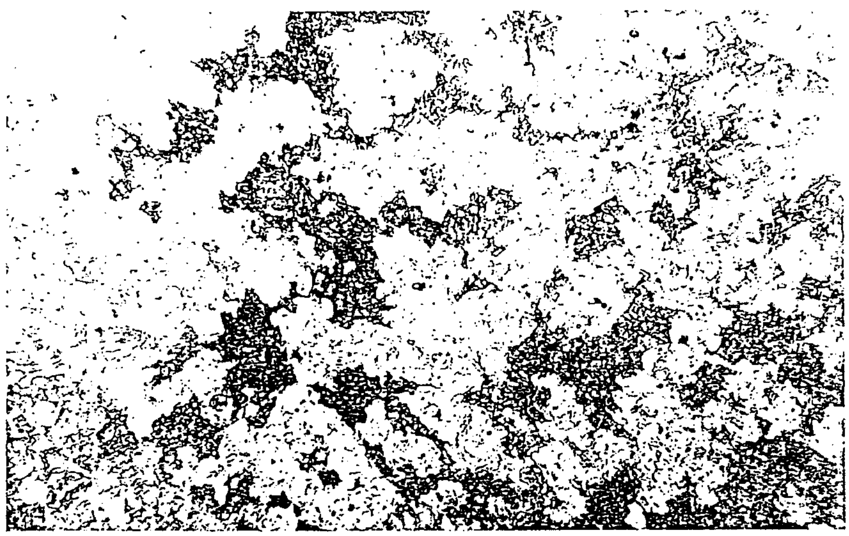

Fig. 22. Photomicrograph of a tourmaline spot. Tourmaline occurs along a network of irregular veinlets interstitial to quartz. Low power (25x).

Muscovite is also replaced by tourmaline; quartz, however, remains intact. The replacement of potassium feldspar proceeds along grain boundaries and in a network of irregular metasomatic tourmaline veinlets, the orientation of tourmaline grains not depending on that of the host . . .

As to their mineralogical composition, the light halos around the tourmaline spots correspond to normal granite, devoid of biotite. The muscovite of the halos lacks patches of leucoxene or any other indication which would point to its origin by muscovitization of biotite."

Origin - According to Němec, the development of tourmaline spots and halos is a type of metasomatism similar to that of granite greisenization. He envisions that, in the spots, the sequence of replacement by tourmaline is biotite-potassium feldspar-plagioclase. This replacement scheme results in a simplification of mineral assemblages from a normal granite outside the spot; to a white halo devoid of biotite; to the tourmaline core, which contains only quartz and tourmaline.

In the spots, the tourmalization of the granite is primarily due to the replacement of potassium feldspar (Němec, 1975) as follows:

$$6K_{0.83}Na_{0.17}AlSi_3O_8 + 3B^{3+} + 3Fe^{2+} + 7H_2O =$$
$$NaFe_3Al_6Bi_3Si_6O_{27}(OH)_4 + 12SiO_2 + 5K^+ + 3H^+$$

Femic components (Mg, Fe, Ti) released by the breakdown of biotite may also be leached by boron-bearing fluids from the host rock. The components migrate to the tourmaline cores and

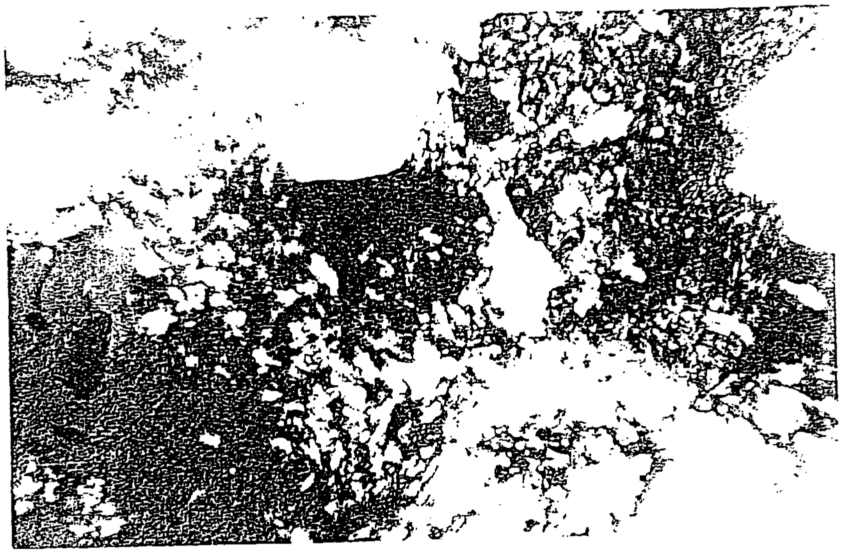

Fig. 23. Photomicrograph of a tourmaline spot showing replacement of altered plagioclase, interstitial to quartz, being replaced by tourmaline. Medium power (160x).

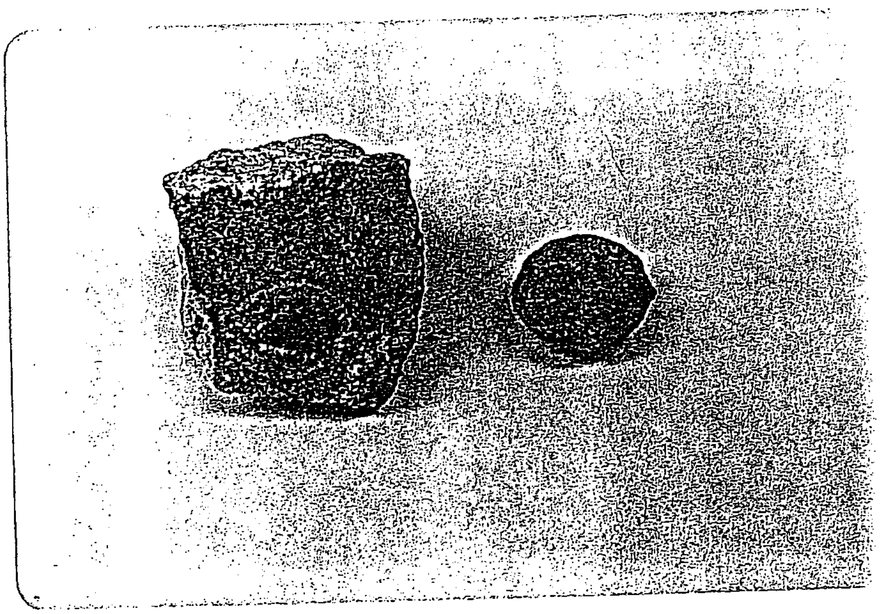

Fig. 24. Tourmaline nodule, right, 1.5 in long. Tourmaline nodule on joint, left, shows circular outline and a core of tourmaline crystals.

help form tourmaline. During this reaction potassium is released and part of the free silica becomes quartz.

Nodules

Tourmaline nodules occur sporadically throughout the main rock phases. They range in size from 0.5 to over 4.0 inches in diameter (fig. 24) and are spherical in shape. The nodules are more resistant to weathering than the inclosing rocks, and stand out in relief on weathered rock surfaces. The nodules consist of a quartz-muscovite-rich outerzone and a quartz-tourmaline-rich core. The size of the outerzone is proportional to their tourmaline cores. Their boundaries are irregular but sharp.

Mineralogy - Tourmaline occurs only in the core and comprises 30.7 percent (table 10) of the material present. It is pale green-blue to slate blue and allotriomorphic. Unreplaced, sharply bounded plagioclase laths are frequently poikilitically inclosed (fig. 25) in a network of irregular tourmaline veinlets, which are interstitial with regard to the quartz grains. Replacement of plagioclase proceeds along grain boundaries and twinning planes. Where replacement is incomplete, the tourmaline gives the plagioclase crystal a bluish tint. Muscovite is also replaced by tourmaline. Occasionally, tourmaline includes minute opaque minerals.

Quartz comprises 57.3 percent of the outerzone and 55.7 percent of the core. In both areas quartz is xenomorphic and ranges in length from less than 0.1 to 0.5 mm. Poikilitic

Table 10: Modal analyses of representative samples of tourmaline spots and nodules.

Sample:	Average Aplite	Spot - Host Rock	Core	Nodule - White Halo	Core
Quartz	31.9	51.0	54.7	57.3	55.7
Plagioclase	35.1	*5.0	*7.0	1.3	9.0
Orthoclase	25.5	--	--	--	tr.
Muscovite	6.3	12.0	1.0	39.3	2.3
Biotite	0.5	--	--	--	--
Opaques	0.2	0.1	tr.	2.0	tr.
Zircon	tr.	tr.	tr.	tr.	tr.
Tourmaline	tr.	tr.	31.7	tr.	30.7
Sericite	--	--	5.3	--	2.3
Pseudomorphs	0.2	--	0.3	tr.	--
Groundmass	--	**33.0	--	--	--

*Plagioclase extensively altered by sericite.
**Consists of sericite, plagioclase, and quartz.

Table 11: Modal analyses of representative samples of tourmaline spots by Nemec (1975).

Locality:	Lavicky			Horni Radslavice		
Sample:	Average Granite	Light Halo	Tourmaline Core	Average Granite	Light Halo	Tourmaline Core
Quartz	33.6	36.2	52.8	31.2	28.7	51.5
Plagioclase	34.4	36.9	9.3	38.7	41.7	28.6
Potassium Feldspar	30.3	27.0	--	24.5	28.0	1.5
Biotite	1.7	--	--	2.5	0.2	--
Muscovite	--	--	--	3.1	1.4	--
Tourmaline	--	--	37.9	--	--	18.7

quartz is more common in the core than in the outerzone. The inclusions consist of plagioclase laths and opaque minerals, the former is often corroded by quartz. Blebs of tourmaline may also be inclosed by quartz, but more often tourmaline incloses quartz.

Muscovite comprises 39.3 percent of the outerzone and occurs as large, greater than 1.0 mm, subhedral to anhedral, primary(?) crystals. These crystals often contain abundant opaque needles and minerals. Muscovite is generally interstitial and contain small, 0.1 mm, inclusions of quartz and plagioclase. It comprises just 2.3 percent of the core and is present as small flakes that decrease in size towards the center of the core.

Plagioclase comprises 1.3 percent of the outerzone and 9.0 percent of the core, and occurs as laths that range in length from 0.01 to 0.4 mm. Almost all are sericitized, some completely; some show albite twins. Others occur poikilitically in tourmaline veinlets and quartz. Plagioclase also occurs interstitially, and is frequently corroded by quartz and tourmaline. Plagioclase is occasionally clouded by opaque minerals and, in rare instances, is rich in opaque minerals.

Opaque minerals are dominantly confined to muscovite crystals, although they do, rarely, occur in quartz grains. They represent 2.0 percent of the outerzone, but occur only as a trace in the core. They are always less than 0.1 mm in

Fig. 25. Photomicrograph of a tourmaline nodule showing partially replaced, inclosed plagioclase laths in tourmaline. Tourmaline is interstitial to quartz. Medium power (160x).

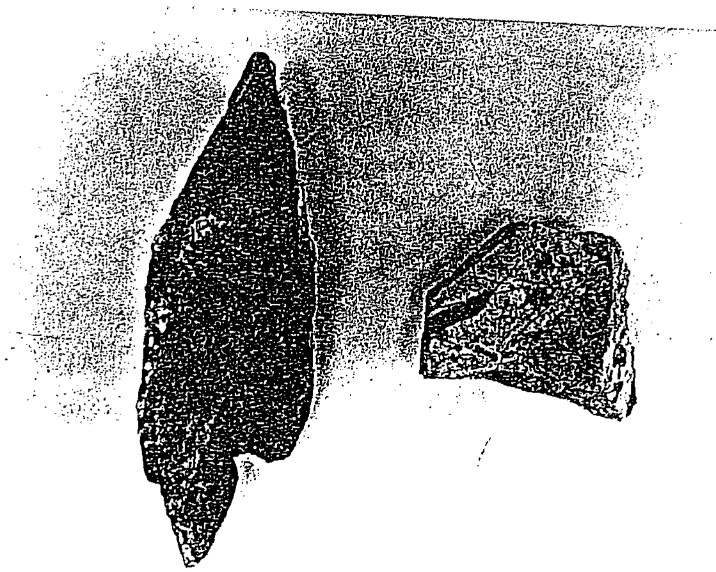

Fig. 26. Left, veneer of fine, felted tourmaline crystals on a joint. Right, tourmaline crystals on a joint. Both are about 2 in wide.

length, and are altered to leucoxene(?) and hematite.

Zircon is commonly present, in trace amounts, as small 0.05 to 0.1 mm, long euhedral needles and anhedral blebs in both phases. Zircon occurs as inclusions in tourmaline; some appear to be partially replaced(?).

Origin - Quartz-tourmaline nodules are rare, although they are fairly common in aplitic granites, which contain large tin deposits (Edwards, 1936). Originally, such nodules were believed to be the result of a magmatic segregation (Barrel, 1901; Knopf, 1913). Later writers, in particular Tilley (1919) considered them to be pneumatolytic in origin, because of the in situ replacement of feldspars. Tilley indicates that intrusion of an aplite into a semi-crystalline, granitic magma would result in a decrease of pressure and the development of bubbles of mineralizers. These bubbles would then rise until they reached a crystal mesh of quartz and feldspar and became attached. After further cooling the boron would attack the biotite and feldspars, converting them into tourmaline at the same time that they deposited the excess silica as secondary quartz. It is more probable, however, that the pneumatolytic formation of the nodules is similar to the formation of tourmaline spots. The only difference being, that the nodules represent more intense alteration and/or require more time to form.

Tourmaline-Bearing Joints

These joints are generally small to medium in size, occurring only locally throughout the mountain. The tourmaline occurs as a veneer of fine, felted crystals (fig. 26), as distinct crystals (fig. 26), as parallel sets of fine, felted masses (fig. 27), and only rarely, as a tourmaline nodule. Tourmaline also occurs on closed joints as individual nodules (fig. 28), or as a series of nodules connected by tourmaline (fig 28).

Mineralogy - Tourmaline occurs on resealed joints as roughly circular, but aligned spots, and comprises 31.7 percent (table 10) of the spots and forms an irregular, but sharp border with the inclosing rock. It is allotriomorphic and pleochroic, light brown, green, and slate blue, and replaces feldspar along a network of irregular tourmaline veinlets which are interstitial between quartz crystals. The veinlets are commonly poikilitic, inclosing plagioclase laths and small quartz grains. Replacement of inclosed plagioclase laths occurs along irregular grain boundaries; relict(?) plagioclase laths which have been totally replaced are present in some veinlets.

Quartz comprises at least 51.0 percent of the rock that contains the spots, and 54.7 percent of the tourmaline spots. It is dominantly anhedral to subhedral, with rare euhedral grains. Quartz ranges in size from about 0.1 to 0.5 mm long and averages 0.2 to 0.25 mm. Some exhibit undulatory extinc-

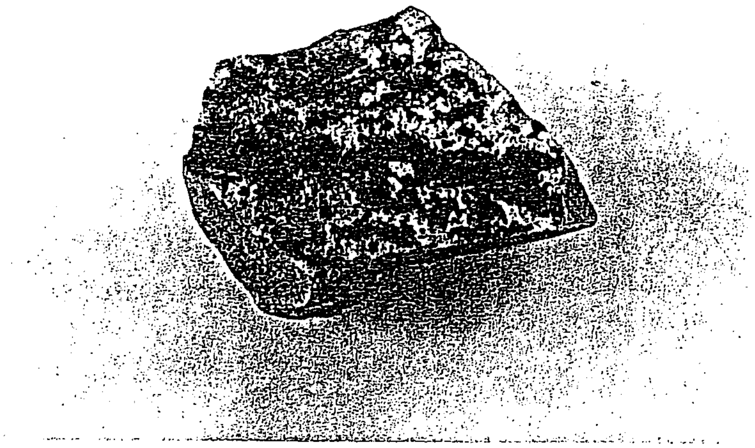

Fig. 27. Parallel, fine, felted tourmaline crystals on a joint. About 3 in long.

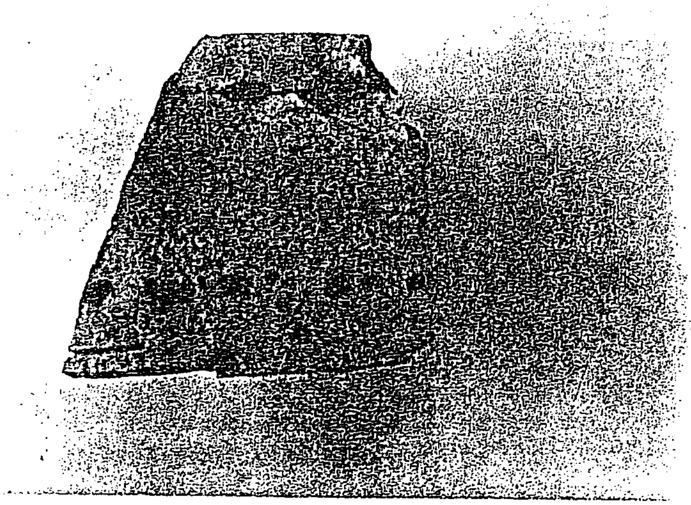

Fig. 28. Bottom, individual tourmaline nodules on a resealed joint. Top, several tourmaline nodules connected by a thin line of tourmaline which marks the resealed joint. Rock is about 3 in across.

tion; others poikilitically inclose plagioclase laths. The quartz-plagioclase boundary is either sharp or slightly gradational. Occasionally a quartz grain contains a trail of small fluid inclusions.

Muscovite comprises 12.0 percent of the rock that contains the spots, but only 1.0 percent of spots where it occurs primarily as sericite.

Plagioclase comprises at least 5.0 percent of the host rock and 7.0 percent of the spots and occurs as corroded, anhedral to rare euhedral laths, about 0.1 mm long, in tourmaline and quartz grains. All are completely altered to sericite.

Opaque minerals are scattered randomly throughout the host rock and the spots, and are present only in trace amounts. These minerals are generally very small, less than 0.01 mm long, and concentrated in the groundmass. Some are present as small blebs in quartz and tourmaline.

Zircon is generally present as small, 0.02 mm long, euhedral needles in quartz. It is present throughout the rock and spots in trace amounts.

Origin - Mineralization by pneumatolytic fluids and/or gases on joints is not well documented. According to Black (1971), tourmalizing solutions are able to penetrate rocks along joints, veins, and shear zones. In a study of the tourmalization in the Dartmoor granite, Brammell and Harwood (1925) describe tourmalization along joints as follows, "During the closing phase, the granite of east Dartmoor was affected by severe tensions. Numerous fissures opened, and afforded passage-way for fluids and gases from depth. These cracks and fissures were infilled with schorlaceous vein-stuff, quartz-schorl-rock, vein-quartz, or ore bodies carrying specular iron-ore or cassiterite, or both of these minerals. The closing phase was marked by local tourmalization of granite in place." The process described by Brammell and Harwood was also probably responsible for the mineralization of the joints of Whistler Mountain. As hot, boron-rich fluids and/or gases moved along joints, tourmalization of feldspar and biotite occurred and resealed some of the joints.

SEDIMENTARY ROCKS

Ordovician System

Vinini Formation

The Vinini Formation was named by Merriam and Anderson (1942), for exposures along Vinini Creek in the Roberts Mountains, 25 miles northwest of Eureka, Nevada. They recognized at least two and possibly three formational divisions; however, they described and mapped only two, a lower and an upper division. The lower division is exposed on the main east fork of Vinini Creek along the east side of Roberts Creek Mountain. Here, it consists of brownish-weathering, dark-gray, bedded quartzites, gray arenaceous limestone and calcareous sandstones that often show cross-lamination. Finely laminated, brownish-gray, and greenish-brown sandy siltstones are present. Shaly partings occur locally and may contain black shales. Amygdaloidal lava flows, tuff-breccia, and greenish volcanic sand occur near the top. The volcanic rocks are extensively chloritized albitized, hornblende andesites.

The upper division consists of a succession of bedded cherts and black shales. The chert layers range in thickness from one to four inches, whereas the shale partings are usually less than one inch thick. Merriam and Anderson (1942) indicate that the chert is more abundant than the shale, and that the chert formed directly or indirectly by volcanic activity. Thin section analysis of the chert reveals microscopic faulting, and small circular areas, which resemble radiolaria. Despite the black color of the shales, and the black to dark-gray and greenish color of the chert when fresh; both shales and cherts tend to weather limonite-brown, cream, white, and grayish white. Common within the black shales are small, rounded nodules, which often contain fossils, such as radiolaria, graptolites, and algae.

At Whistler Mountain, the Vinini Formation is near its most eastern extent, and commonly constitutes small hills or exposed ridges on valley sides and floors. Outcrops are generally poor and mantled with float. Vinini is present in sections 21, 27, 28, 33, T. 21 N., R. 52 E., as float. The float consists of individual subangular to angular chert fragments which vary in color from black to a dark gray; where they are stained, to a light brown or a dusky red. Fragments range from less than one-half to two inches in length. The Vinini also caps several small, low lying hills which, in places, have been sufficiently eroded to expose the underlying Devils Gate Limestone. Where the Vinini is exposed the individual outcrops are fairly small, 3 ft x 10 ft x 4 ft (fig. 29) and limited in occurrence. At a distance, these outcrops seem to be dark, rounded, and badly weathered. However, closer examination of several outcrops reveals angular and fractured chert, with possible bedding. Many of the fractures are cemented by silica and/or have acted as conduits for fluids which have stained some rocks light brown to dusky red.

In sections 14 and 23, T. 21 N., R. 52 E., the Vinini outcrops strongly resemble the previously discussed exposures. Here, outcrops are generally small, 3 ft x 10 ft x 3 ft, badly weathered and fractured. Most outcrops are mantled by float that varies in size from less than one to over eight inches in length, but averages one to two inches. The float is angular to subangular, grayish black to black, stained in places by iron-oxides to light brown or dusky red, and comprised principally of chert. Where the Vinini is in contact with the pluton, no metamorphism or color change is apparent.

Float covered outcrops are the primary occurrence of Vinini in section 14, T. 20 N., R. 52 E.; minute folding, silica-filled fractures are characteristic. The dominant colors are dark-gray to black, weathering to green, blue, and reds. The fragments are small, one-half to three inches, and angular to subangular. A brown, finely crystalline limestone containing several small layers of chert occurs in this area.

According to Merriam and Anderson (1942), "Where the base of the thrust plate is exposed, it is usually marked by a very pronounced breccia zone, at least 30 to 40 ft thick. These breccias are best developed where the cherty layers of upper Vinini have been fragmented . . . . The

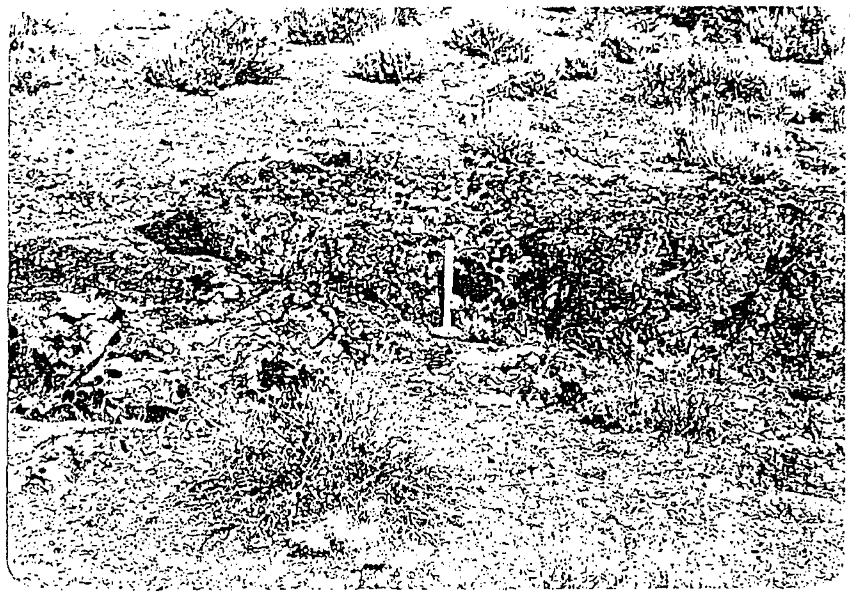

Fig. 29. Vinini outcrop, hammer is about 1 ft long. Looking west.

Fig. 30. Devils Gate Limestone mud breccia clasts, dark gray, in a lighter gray matrix. Looking northwest.

resistant thrust breccias are often silicified and stained by iron-oxide so that they outcrop locally as brownish-black crags." This is a good description of the Vinini exposures of this area. It is suggested that the Vinini of this area represents part of the base of the Roberts Mountains thrust system.

The Ordovician age of the Vinini, is based upon graptolites found in black shales by Merriam and Anderson (1942).

Eureka Quartzite

This formation was named and defined by Hague (1883) for the Eureka mining district. He designated the entire district the type area. However, because the formation is highly faulted and brecciated, Kirk (1933) suggested the well-exposed section of the west side of Lone Mountain as the type locality. According to Merriam (1940), the thickness at the type locality is about 350 ft, and consists of two divisions (Nolan and others, 1956).

The lower one-third is composed of fine- to medium-grained quartzite, strongly cemented by silica, weathering purple, red, brown, or white, and characterized by the presence of cross-bedding. The upper two-thirds is composed of massive, gleaming white, vitreous to sugary, fine- to medium-grained quartzite, cemented by silica.

Roberts and others (1958) suggest that the essential identity in age and composition of the Eureka with some of the quartzites in the Valmy and Vinini indicates a common source. These latter formations were "formed in a deep-water environment in another part of the same geosyncline." (Roberts and others, 1967). However, Nolan and others (1956) suggest that the Eureka may be a subaerial deposit formed during ermergence with restricted marine embayments.

The Eureka is in conformable contact with the Pogonip Group at its base, and with the Hanson Creek Formation as its upper boundary at Lone Mountain. The age assignment of the Eureka Quartzite is determined by the Early and Middle Ordovician age of the underlying Pogonip Group, and the Middle(?) and Late Ordovician age of the overlying Hanson Creek Formation (Roberts and others, 1967).

In the SW 1/4 of section 14, T. 20 N., R. 52 E., (plate 1) the Eureka Quartzite occurs as breccia with pebble- to cobble-sized clasts. The clasts consist of vitreous, white, strongly cemented quartzite of the upper division, which form rugged outcrops, scarps, and large boulders. The Eureka also occurs as large boulders north-northwest of the aforementioned exposure, and south of Devils Gate in a nearby valley. The boulders are vitreous, white, densely cemented quartzite, which lie upon the younger alluvium of the valley.

In section 5, T. 20 N., R. 53 E., the Eureka Quartzite forms a hill over 120 ft high, which consists of quartzite breccia. The clasts are vitreous, white, quartzite; the cement is silica. The hill trends northwest and was partially eroded by current action of a former Pleistocene lake.

A smaller hill just north of the main outcrop in section 5, is also composed of quartzite boulders or breccia clasts cemented by silica. Colors vary from white to pale blue, light gray, and dark gray. Polishing by desert winds is evident on many of the boulders.

Silurian System

Lone Mountain Dolomite

Hague (1883) named the Lone Mountain Dolomite for exposures on Lone Mountain. As originally defined, the formation included all units between the Eureka Quartzite and the Nevada Limestone. Merriam (1940) redefined and restricted the Lone Mountain Dolomite to exclude the Hanson Creek and Roberts Mountains Formations.

Merriam (1940) measured a thickness of 1570 ft of light-gray and darker gray, fine-grained to saccharoidal dolomites and dolomitic limestones at the type locality. The formation is characteristically thick to massively bedded, and commonly weathers to a light or medium gray. The lower contact is gradational and marked within a zone where the dark-gray dolomite of the Roberts Mountains Formation changes to light-gray dolomite of the overlying Lone Mountain (Merrian and Anderson, 1942). Nolan and others (1956) report that the upper contact with the Devonian Nevada Formation is gradational in places, but is fairly abrupt in the Diamond Mountains.

Since the Lone Mountain is sparsely fossiliferous, age determination is generally based upon the paleontology of the underlying and overlying formations. However, Roberts and others (1967) report that in the northern end of the Fish Creek Range it contains brachiopod faunas of Late Silurian age.

In the southwest 1/4 of section 14, T. 20 N., R. 52 E., (plate 1) breccia which contains clasts of a light-gray, medium-grained, recrystallized dolomite of the Lone Mountain occurs. In section 24, T. 21 N., R. 52 E., and section 5, T. 22 N., R. 53 E., the Lone Mountain Dolomite forms a low-lying hill which trends northwest. These two hills consist of a light gray, fine to very fine-grained, brecciated dolomite, which weathers light brown. Numerous dark veins are present throughout the dolomite and produce a fragmented appearance. Caliche is also present on several exposed surfaces. The southern locality also exhibits angular blocks of dolomite ranging in size from less than one in to almost two ft in length. Rhino-skin weathering is present on the low-lying surfaces at both hills. Numerous prospect pits are also present on the two hills.

Devonian System

Devils Gate Limestone

Originally, the Devils Gate Limestone was part of Hague's (1883) upper division of the Nevada Limestone. Merriam (1940) separated this upper division from the Nevada and designated the strata on the north side of Devils Gate as the type section of the Devils Gate Formation. The lower contact is drawn at the "top of the highest bed bearing Stringocephalus," and the upper contact as the top of the Cyrtospirifer zone. Lithologic criteria were established in 1956 by Nolan and others who renamed the Devils Gate Formation, the Devils Gate Limestone.

This limestone is composed of two members, the Meister Member and the Tollhouse Canyon Member. The Meister Member was named after the Meister mine on Newark Mountain by Nolan and others (1956). The lower contact is gradational with the underlying Nevada Formation, and is marked by a change from limestone to dolomite. The Meister Member is composed primarily of thick-bedded, dark- to blue-gray, fine-grained limestone. The upper 30 ft of the Meister Member is marked by six-inch beds of whitish-weathering dolomite alternating with darker limestone. Merriam and Anderson (1942) report abundant stromatoporoids and Cladopora in the dolomite of this member.

The upper, or Hayes Canyon Member, is named for Hayes Canyon, now called Tollhouse Canyon which is located on the west slope of Newark Mountain (Nolan and others, 1956). The conformable contact with the Meister Member is located at the base of a dark-gray, limestone which contains abundant oolites and encrusted ostracodes. It is about 780 ft thick and is composed of thick-bedded, dark-gray limestone with small lenses of chert. The upper portion is thinner bedded and darker in

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color, and also contains "mud-breccias."

Merriam (1940, 1963), and Nolan and others (1956), established a Late Middle Devonian and Late Devonian age for the Devils Gate Limestone. This determination was based on the identification of Spirifer argentarius, Phillipsastraea, Cyrtospirifer, Leperditia, and Tylothyris in this unit.

Joining the two incomplete sections at Devils Gate (1095 ft), Modac Peak (1800 ft), Merriam and Anderson (1942) indicate a thickness of 2065 ft for the Devils Gate Limestone. On Newark Mountain, Nolan and others (1956) report 1200 ft of section, while further east, in the Diamond Mountains, there is only 750 ft of section. They suggest eastward thinning of the Devils Gate by replacement of the higher beds of limestone by the Pilot Shale.

The best exposures of Devils Gate Limestone are at Devils Gate where it forms near vertical cliffs over 400 ft high. Calcite veins are common in fractures and faults. Silicified brachiopods and rugose corals are also common at Devils Gate.

The exposure of Devils Gate Limestone in the southwest 1/4, section 3, T. 20 N., R. 52 E., (plate 1) consists of a very fine to cryptocrystalline limestone, dark-gray to grayish black on a fresh surface, weathering to a medium- or light-gray. Individual limestone beds average 3 to 4 ft thick, with medium, 1.5 to 2 ft, and thinner, 2 to 4 in, beds interspersed throughout. Commonly the more massive beds form low-lying ridges 5 to 10 ft in height; veins and fractures are cemented by calcite and some silica. Outcrops are very well exposed, with an overall rounded and slightly pitted appearance. At the southern end of the exposure, several partially silicified rugose corals and a tabulate coral are present. Bryozoans may also be present here. Mud breccia (fig. 30) clasts several inches in diameter, subangular to subrounded, and a darker blue-gray than the surrounding lighter matrix, occur here.

Merriam (1963) touches briefly on these mud-breccias: "Limestone pieces, ranging in length from less than 1 in to 8 in, are imbedded in a matrix of virtually the same sediment, but usually having a different shade of gray. More than half of the fragments are angular, others show some rounding. Commonly the fragments include fossils not found in the matrix, but there is no indication of long transportation. The mud-breccia is not made up of flat pieces that are rather closely spaced like some so-called edgewise conglomerate. Although slump bedding and evidence of flowage were not noted, these deposits are probably a result of oversteepening and undermining by wave and current action along banks of partly consolidated sediments."

Northward along this exposure, the number of mud-breccia clasts and fossils decrease in number, and grade transitionally into massive limestone. These also are locally stained moderate- to light-red.

In sections 28 and 27, T. 21 N., R. 52 E., the limestone is very finely crystalline and weathers a light bluish-gray to medium light gray. A fresh surface is generally dark gray to black in color. The limestone is usually thin bedded, 6 to 8 in, with small intercalated beds of fetid, black shale. Outcrops are small, 1.5 ft x 7 ft x 0.5 ft, and cap several of the surrounding hills. Calcite fills many fractures, and partially replaces a tabulate coral at one hill top. At one location, a pale red, platy, gritty, shale is in a conformable (?) contact with the underlying limestone.

At section 14, T. 21 N., R. 52 E., the limestone is very finely crystalline, black in color and weathers to a medium bluish-gray or pale blue. Thin beds, 3 to 4 in, of limestone frequently contain small, thin, 0.5 in, black, cherty laminations with minor folding (fig. 30). At several locations, the black cherty layers exceed several inches in thickness, and overlie several smaller, very fine, sandy, pale yellowish brown layers. These sandy layers are separated by limestone or chert. Calcite and silica are commonly present in veins or fractures. Near the contact between the Vinini and Devils Gate Limestone, the chert beds disappear, and the limestone becomes increasingly fractured and is replaced by silica. Brecciation of the limestone marks the contact. The breccia fragments are angular to subangular, about 0.5 in diameter, and cemented together by silica. The general trend of the limestone breccia is N. 5° W., which corresponds approximately

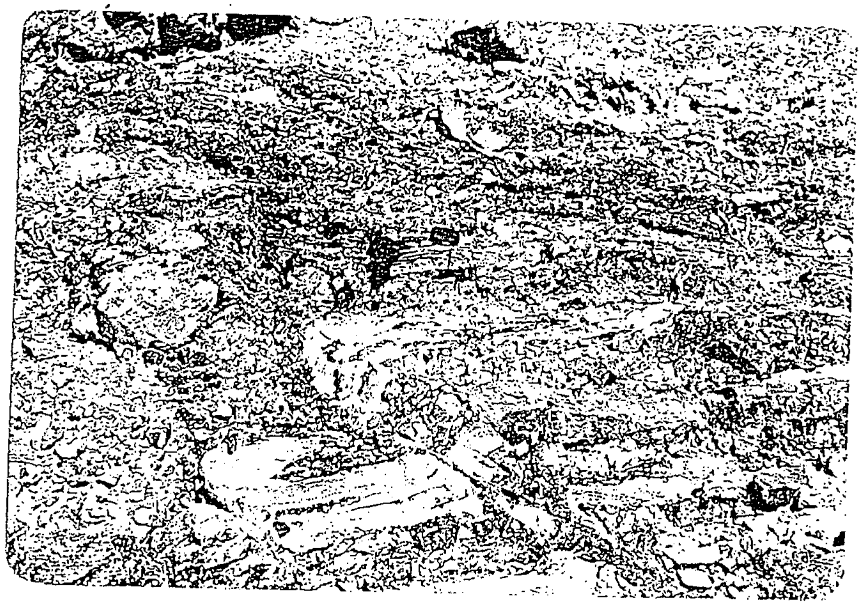


Fig. 31. Folded and faulted Devils Gate Limestone at the thrust contact of the Roberts Mountains thrust system. Looking north.

with the general trend of the Vinini in this area.

Mississippian System

Chainman Formation

Hague (1883) associated black Lower Carboniferous shales in the Eureka district, with a type locality in the White Pine district, named the White Pine Shale. However, because of its vague definition, Spencer (1917) used the named Chainman Shale for the Lower Carboniferous shales of the Ely district. Brew (1971) changed the name to the Chainman Formation based upon the nonshaly lithologies in the formation, and recognized two informal facies, the Water Canyon and Black Point.

The Water Canyon lies unconformably upon the Pilot Shale and consists primarily of clay rock and clayey silt-rock, which is usually dark gray, black or grayish green and weathers to shades of brown or olive. Minor beds of sandstone and conglomerates are present, and contain plant impressions. The Water Canyon may obtain a thickness of about 2400 ft in the Diamond Mountains.

The Black Point is a sandstone, cobble conglomerate which also contains siltstone and claystone. Portions of the Black Point resemble the Water Canyon, but overall the Black Point facies is coarser. The Black Point varies in thickness from 3500 to 4000 ft in the Diamond Mountains.

Diamond Peak Formation

Hague's (1883) Diamond Peak Formation consists principally of siltstone, sandstone, conglomerate, with lesser amounts of claystone and limestone. Brew (1961a) described the type section, and in 1971 he carefully defined the unit and described eight informal members. The Diamond Peak conformably overlies the Chainman Formation and is over 3500 ft thick at the type section. In general, the lower members are more shaly and the upper beds more conglomeratic.

Nolan and others (1956) note that the cherts of the Vinini can be matched lithologically with the cherts in the Diamond Peak Formation. Accordingly, their presence in Upper Mississippian sediments "indicates that in later Mississippian time the late Paleozoic geanticline in central and western Nevada had risen high enough and rapidly enough to shed coarse debris from the Vinini Formation that had by then been exposed."

Nolan and others (1956) regard the fossils in the Diamond Peak Formation as Late Mississippian. However, there may be evidence that the uppermost part of the formation is Pennsylvanian in age (Easton and others, 1953).

Since the lithologies are similar in the area, the two formations are listed as Mississippian Undivided.

Mississippian Undivided

These sediments occur primarily as float throughout the area (plate 1). Mississippian sediments south and just north of U.S. Highway 50 consist of black to dark-gray calcareous shales, which weather brown, gray, black, and green. They are poorly cemented reddish-brown sandstone consisting of angular chert grains, and a fine-grained reddish brown to light-brownish-gray conglomerate consisting of angular to subangular chert pebbles in a silica cement. In sections 26 and 27, T. 20 N., R. 52 E., the Mississippian sediments are capped by pediment gravels.

Outcrops on the western flank of Whistler Mountain, are commonly small, 2 ft x 5 ft x 5 ft, and partially buried under their own float. Outcrops are sparse, the rocks are strongly jointed and poorly bedded. Both outcrops and float are composed of very fine to coarse rounded, subrounded to subangular chert grains. These grains represent 80 to 90 percent of a rock sample; a silica matrix comprises the remainder. A freshly broken surface exhibits grain to grain contact as well as a darker color than the exposed surface. Commonly, these Mississippian sediments weather black, very dark red, pale brown, yellowish brown and grayish blue. Several broken surfaces reveal small, dark yellowish orange spots, which may have been pyrite. Float material varies in size from 1 in to 2 ft in length, but is generally 4 to 6 in long and angular. Minor banding due to iron-oxide(?) is also present.

At section 31, T. 21 N., R. 52 E., a somewhat more varied Mississippian sediment occurs. Here, the sand grains vary from very fine to very coarse, subrounded to rounded, with less than 5 percent of grains being subangular. Black chert comprises about 50 percent of the grains, while the matrix consists of very fine grains, 5 to 10 percent, and the remainder consists of other colored chert and sand. Siltstone clasts averaging 1 x 3 in or more are present in minor amounts and occur sporadically throughout. However, stratigraphically higher, both the size and number of these clasts increase. At some localities, the conglomerate fines upward into a medium bluish-gray shale. These shales contain lenses of medium to very coarse, subrounded to subangular chert and sand grains, which comprise between 20 and 30 percent of the shale. A dusky red iron-stain is very common on the finer grained conglomerates. Exposures of the Mississippian sediments are limited primarily to stream channels, where they may be capped by 15 ft of pediment gravels. The conglomerates form prominent ledges along the stream about 1 ft high, while the shales break into thin, flat, and elongated fragments. Small joints, which break around individual grains, are common in the conglomerate. These small rectangular blocks provide part of the float material found downslope.

Quaternary System

Older Alluvium

Older alluvium is present as an unconsolidated to slightly consolidated, veneer on the bedrock-pediment surface. It is dissected by ephemeral streams and, near the southwest flank of Whistler Mountain, stands over 100 ft above the valley floor. It consists of poorly sorted, unconsolidated to semi-consolidated gravels. It contains clasts of Paleozoic and Mesozoic sedimentary rocks that range in size from granules to boulders. The clasts consist of subrounded to subangular, dark-gray Devils Gate Limestone; black and green chert and shale of the Vinini Formation; brown, gray, and black sandstone and conglomerate of the Mississippian rocks. The Mesozoic clasts consist exclusively of white to moderate-orange-pink quartz-monzonite from Whistler Mountain and associated sills. These clasts are often stained brown or black and range in size from gravels to boulders, the latter are sometimes 3 ft in diameter. The clasts of the older alluvium occur in a matrix that ranges from silt to sand, and which is probably derived from the same source as the clasts. The clasts of Devils Gate Limestone and quartz-monzonite are frequently coated with caliche; especially if they have just recently been exposed.

Younger Alluvium

This occurs generally only near Anchor Peak and Slough Creek. The alluvium at Slough Creek constitutes the flat, hard valley floor, and consists of compacted, light-gray silt and clay with minor amounts of coarser sediment. Further from Slough Creek, the valley floor is unconsolidated and is composed of loose sand and gravel. In section 23, T. 20 N., R. 52 E., the alluvium consists of loose, medium-grained quartz sand, which is mixed with small amounts of pebbles and cobbles of Devils Gate Limestone and quartz-monzonite. In the SW 1/4, section 13, quartz-sand is mixed with gravels of chert from the Vinini Formation. In section 24, 25, T. 21 N., R. 52 E., the alluvium consists of a thin veneer, 1.5 in thick, of desert pavement, which is composed of subangular to subrounded chert of the Vinini Formation and quartz-monzonite from Whistler Mountain. The longest dimension of these fragments range from 0.25 to 4.0 in. Beneath the pavement is 6 in of fine silt which contain fragments of chert and quartz-monzonite rocks that range in length from 0.25 to 0.5 in. Beneath this silt layer is a hard-packed, red clay which also contains sand-sized fragments of chert and quartz-monzonite.

VOLCANIC ROCKS

Volcanic rocks are present in sections 15 and 16, T. 20 N., R. 52 E. These are water-laid volcanic rocks, which have been faulted some time after their original deposition.

The volcanics in section 15 rest unconformably on the Vinini Formation, and are erosionally truncated by the older alluvium of the pediment surface. According to Dill (1980), there are three different volcanic lithologies, a tuffaceous sandstone; a conglomeratic, tuffaceous siltstone and sandstone; and a welded tuff.

The tuffaceous sandstone is light gray to white in color, commonly with a pinkish or greenish tint. It is composed of medium- to coarse-grained crystal and glass fragments set in a similar, but finer matrix. The tuff is thinly, 0.25 to 1.0 in, bedded. The tuffaceous sandstone is poorly indurated, friable, and brittle.

The conglomeratic, tuffaceous siltstone and sandstone is massive and pinkish-gray in color. Its matrix consists of crystal and glass fragments of volcanic origin, as well as some non-volcanic sand and silt. Pebbles and cobbles of rhyolite, volcanic glass, basalt, and other igneous rocks are present. The long axes of the clasts show a preferred orientation. The tuff is poorly consolidated and friable.

The welded tuff is reddish-purple and pink in color. It occurs only as loose fragments and is fairly dense and hard.

It closely resembles a light-colored obsidian. Flow banding and lithophysae are present.

According to German (1981) the bedded volcanics in section 15 exhibit some degree of size sorting of clasts. The clasts consist of angular chert, pyrite, and rhyolite. Thin section analysis reveals the presence of orthoclase, biotite, and glass. The quartz shows undulatory extinction and andesine is zoned. Glass is the dominant constituent, representing 60 to 70 percent of the tuff. Some silt and clay are present as a finer matrix.

The non-bedded volcanics in section 15, commonly are pocked as a result of differential weathering. Holes range in size from 3 to 4 inches in diameter. Glass comprises 60 to 80 percent of the rock while quartz, plagioclase, biotite, brown hornblende, augite, and clay constitute the remaining 20 to 40 percent (German, 1981).

In section 26, the tuff rests unconformably(?) on the semi-consolidated older alluvium. This lithic tuff is light-gray to tan in color. The lower portion contains pebbles and cobbles. It covers an area over 100 ft in length and forms ridges over 6 ft in height, and appears to be more resistant than other members of this group.

The age of these volcanic rocks is unknown. However, Blake and others (1975) report that Eureka was an active volcanic center, primarily during Oligocene time. According to Armstrong (1970) silicic volcanism was fairly common in east-central Nevada during the Oligocene and Miocene. The rhyolite tuff which comprises Target Hill, just southwest of Eureka is dated as 38 ± 5 m. y. (Jaffe and others, 1959). Similar rhyolites and rhyolite tuffs near Eureka and further south are dated between 34 and 35 m. y. (Blake, 1968). In light of the above, it seems reasonable to assign an Oligocene age to these volcanic rocks.

STRUCTURAL GEOLOGY

Regional

The structural geology of the Great Basin is complex because of abundant normal faults, reverse faults, low-angle thrust faults, and folds. As part of the Basin and Range province, the Great Basin has been extensively studied. King (1870) believed the ranges to be a series of eroded folds, formed in late Jurassic time. Gilbert (1874, 1875) proposed that the ranges originated by block faulting and recognized two distinct types: 1) tilted blocks which form the mountains; 2) down-dropped blocks which form the valleys. King (1878) favored an origin based on diastrophism; first by folding and thrusting and second by block faulting. Spurr (1901) indicated erosion and faulting as the reason for the Basin and Range structure. Louderback (1904), however, supported block-faulting. Nolan (1943) and Mackin (1960) supported Louderback and indicated that block-faulting was, at least in part, if not entirely responsible for the formation of Basin and Range structure. Other authors supported tilting of blocks as the only way to form the present day structure (Gilluly, 1928; Moore, 1960; Gilluly and Gates, 1965). The horst and graben concept has also been embraced by many authors (Fuller and Waters, 1929; Cook and Berg, 1961; Stewart, 1971). Basin and Range structure is believed by others to be the result of deep-seated extension and fragmentation related to plate tectonics (Menard, 1964; Stewart, 1971, 1975).

Recent geophysical work on the Great Basin "reveals that its crust is thin and has a distinct velocity layering" (Churkin and McKee, 1974). According to Priestley and others (1980) the average structural model of the Great Basin would include a crust 35 km thick, an upper mantle lid of 29 km, and an extreme low velocity layer about 120 km thick. They also report an average crustal thickness of 35 km for the whole of the Great Basin, which thins in the northern Great Basin to 25 km. Seismic studies by Churkin and McKee (1974) indicate that the crust of the Great Basin is intermediate between typical continental and oceanic crust, and resembles that of marginal ocean basins. They also report that the Great Basin crust is at "an intermediate stage in the process of conversion of oceanic crust into stable continental land-mass or craton by accretion of oceanic geosynclinal material to a Precambrian continental nucleus." The present alignment and topography of the Basin and Range Province is due primarily to orogenic movements during Tertiary and Quaternary time (Roberts and others, 1967).

The oldest Tertiary faults in north-central Nevada trend east-west in contrast to later structures which trend north to northeast (Robinson, 1970). Seismic data on several valleys in northeastern Nevada (Railroad, Diamond, Mary's River, and Goshute Valleys) "define an assymetrical basin bound along the eastern flank by a major listric normal fault with about 10-15,000 ft of displacement. The western flank is defined by a gentle east dipping ramp. Seismically the trace of the listric fault is interpreted to dip westward and sole into the Paleozoic section exploiting regionally recognized Mesozoic decollment surfaces. The Tertiary depocenter adjacent to this fault, shifted from west to east with continued slippage through time, the greatest movement occurring in Miocene and post-Miocene time. In the strike direction, valleys are separated into at least two subbasins by an east-west structurally high axis. The axis is postulated to be the result of a tear fault associated with movement along the listric normal fault" (Effimoff and Pinezich, 1980).

Whistler Mountain Area

Thrust Fault

Basal portions of the upper plate of the Roberts Mountains thrust system are exposed along the flanks and south of Whistler Mountain. Ordovician sedimentary rocks overlie younger carbonates and clastics of Devonian and Mississippian age, respectively. In section 14, T. 21 N., R. 52 E., the sole of the upper plate is in direct, thrust contact with the Devils Gate Limestone. The contact is marked by breccia, intense silicification, minor folding, and a large variation in strike and dip components. In sections 27 and 28, the thrust plate contains numerous, small, exotic blocks of

Devils Gate Limestone. The limestone is present at the top of several small hills, which are surrounded by siliceous shales of the thrust system. In section 14, T. 20 N., R. 52 E., the thrust system contains a hill composed of breccia. The clasts of this breccia consist of the Pogonip Group, Eureka Quartzite, Hanson Creek Formation, Roberts Mountains Formation, and the Lone Mountain Dolomite; the cement is silica and calcite. Despite this intense brecciation, some stratification, trending northeast, is present. Bedded cherts and an andesitic tuff capped by chert are present at Anchor Peak, and represent part of the upper plate.

Minor slickensides are present throughout the thrust sheet which surrounds Whistler Mountain. The slickensides are always reddish-brown. Breccia zones also occur locally and may exceed several hundred feet in length. In section 24, T. 20 N., R. 52 E., a breccia zone over 1000 ft in length is parallel to the thrust contact (Busch, 1981).

Folds and Microfaults

Folding is limited primarily to the Vinini Formation and the Devils Gate Limestone. The folds are generally small isoclinal or drag folds. At Anchor Peak, the Vinini cherts have suffered minor drag folding and faulting. Fold axes generally trend northwest and plunge over 40°. Microfolds 4 in or less in length are also present here, and are frequently overturned, recumbent, refolded, and irregular. Fold axes are almost horizontal and trend N 24° E to N 15° W.

Microfaults with less than 1 in of displacement are also common. These faults intersect the nearly horizontal, north-trending bedding surfaces of the Vinini chert (Dill, 1980).

In section 26, T. 20 N., R. 52 E., minor folding along the western edge of Devils Gate is present. The limestone exhibits a series of small, 6 ft long by 4 - 8 in high, folds that plunge steeply to the west. The folds axes are almost horizontal and trend north-northwest. Minor folding due to faulting is also present in section 23. According to Busch (1981) a small syncline plunging 32° with an axial trend of N 2° W is present southeast of the center of section 23.

Normal Faults

East-west normal faults are common south of Whistler Mountain, and a major one is present at Devils Gate. Here, the block just north of U.S. Highway 50 has been displaced downward with respect to the southern block. The northern block exposes more of the upper Devils Gate Limestone, and contains minor amounts of Pilot Shale. The southern block contains no Pilot Shale, but does contain sporadic dolomite beds at its base. These dolomite beds can be correlated to the lower member (Meister Member) of the Devils Gate Limestone. A breccia zone about 50 ft wide is also present on the southern block, and shows minor slickensided surfaces with minor iron and carbonate mineralization.

Whistler Mountain is flanked on the east and on the west by major, north-south, trending faults (plate 1). The eastern fault is partially concealed under Tertiary and Quaternary alluvium. However, several large exposures of Paleozoic rocks just east of Whistler Mountain delineate the fault, and suggest a north-northwest trend. The fault is further identified by anomalous magnetic lows, which surround the Paleozoic sediments (plate 4), intense brecciation of the Eureka Quartzite, calcite veining and minor brecciation of the Lone Mountain Dolomite.

The western fault is much more evident. Here, the fault forms a major fault line scarp of Devils Gate Limestone in section 23, T. 20 N., R. 52 E. In section 14, the fault truncates the breccia hill of Paleozoic sediments. In section 15, the fault re-exposes large blocks of Mississippian sedimentary rocks. North of section 15 and south of section 26, the fault is traced by large, round, Eureka Quartzite boulders present on the alluvium. These boulders occur in a narrow, north-south trending line, which can be followed, especially to the south, over several miles. The fault is lost beneath the older alluvium in section 10, but can be identified again in section 34, T. 21 N., R. 52 E., on aerial photographs. Northward from section 34, the fault is marked by a significant color change between older alluvium and the Vinini Formation. The general trend of this fault is north-northwest.

Yahoo Canyon is a major normal fault, which extends southward from section 22, T. 20 N., R. 52 E., over 5 miles (Merriam, 1963). However, very little actual movement has taken place. This fault trends approximately north-south.

In the west-central portion of section 23, T. 20 N., R. 52 E., an upthrown wedge of Devils Gate Limestone is present. This wedge is bounded on the west and southwest by normal faults, and hinged on the northeast (Dill, 1980).

Joints

Joints are generally not well developed or systematic in their distribution. However, in the interior portion of the pluton joints tend to be systematically distributed and to dip at about 45° (figs 32, 33). Joint trends are also variable (figs. 34, 35).

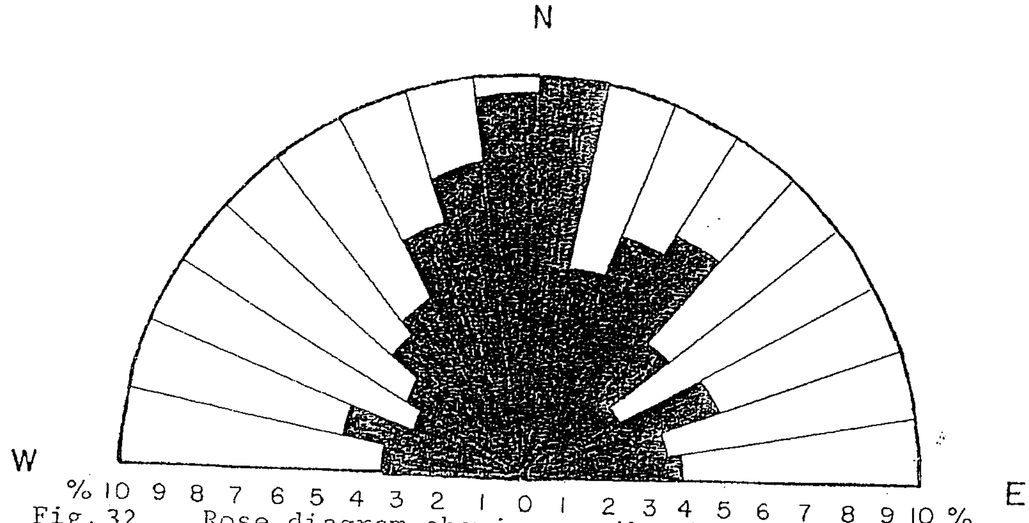


Fig. 32. Rose diagram showing strike direction of joints.

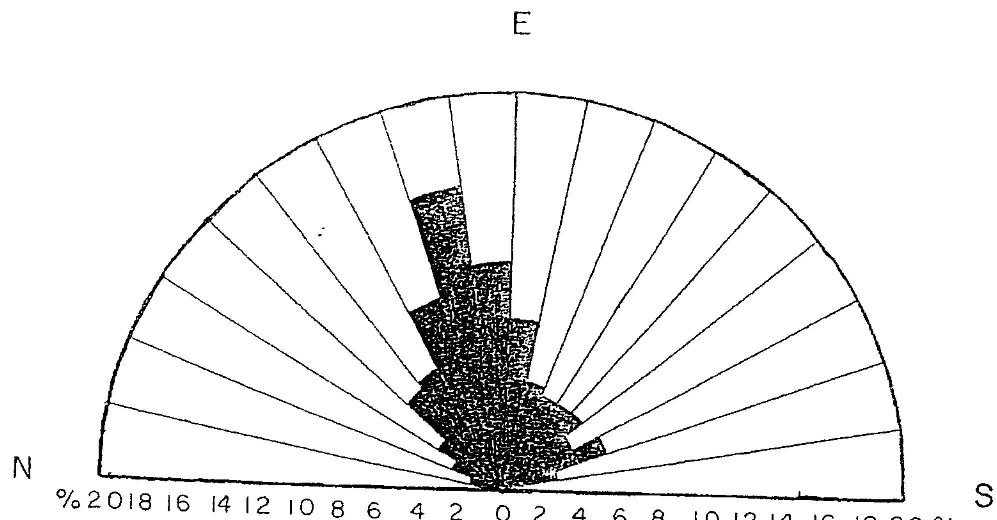


Fig. 33. Rose diagram showing dip direction of joints. Majority of joints dip east at 70 to 80 degrees.

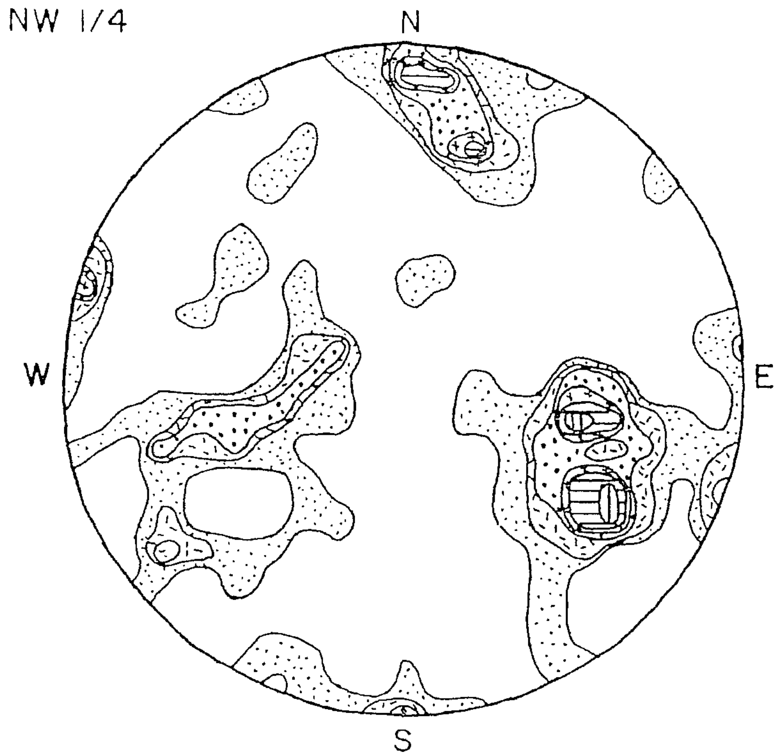
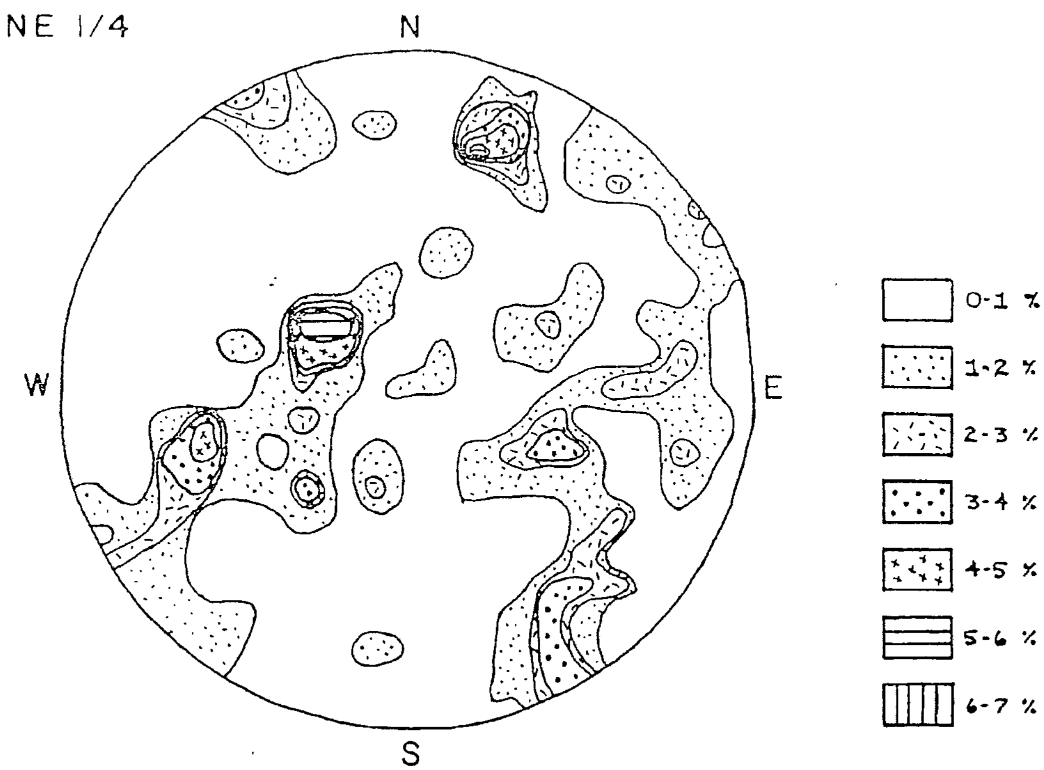


Fig. 34. Contour diagrams of joints in the northern half of Whistler Mountain.



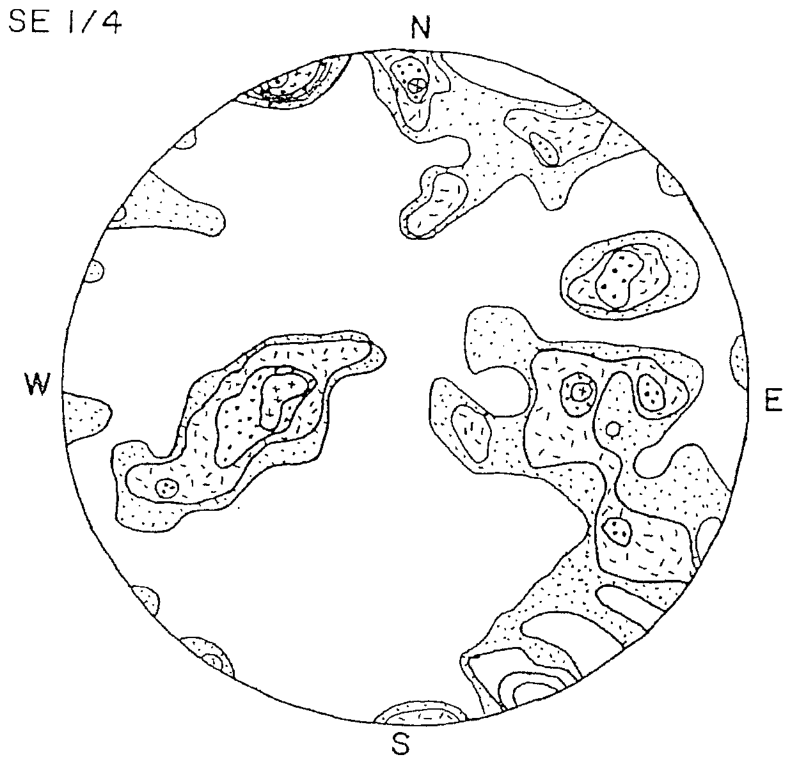
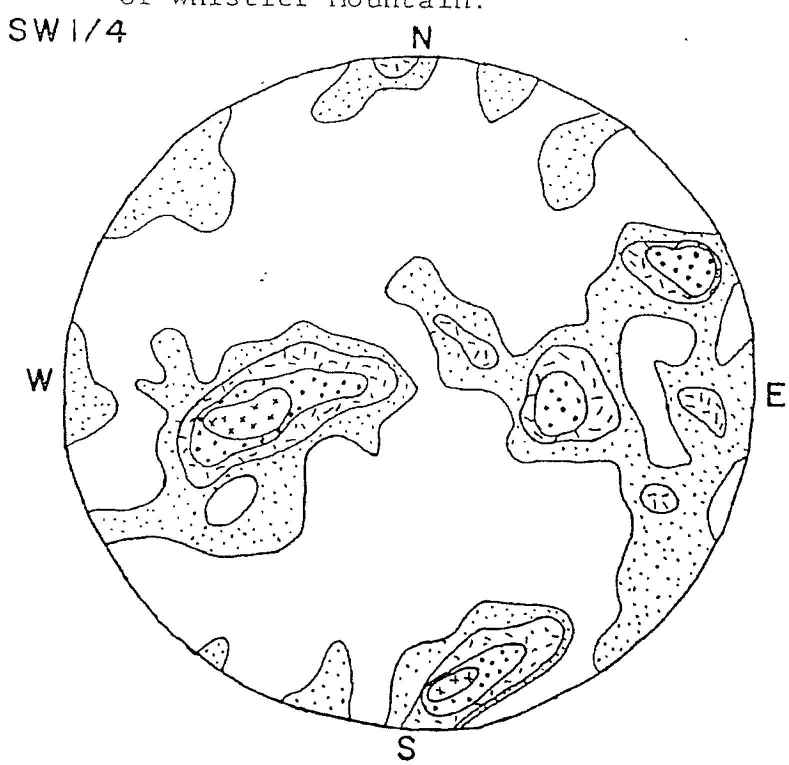


Fig. 35. Contour diagrams of joints in the southern half of Whistler Mountain.



ECONOMIC GEOLOGY

Eureka District

The Eureka district, Tps. 18 and 19, N., R. 53 E., produced at least $122 million from replacement deposits in Cambrian limestone and dolomite (Nolan, 1962). The first mineral discovery was made in New York Canyon on September 12, 1864. The ore contained a rich combination of silver and lead. Further discoveries were made in the next three years. However, because of the difficulty in separating the metals, the district was almost abandoned. In July, 1869, the problem in smelting was solved and the mining district grew rapidly. By 1885, production began to drop as the bonanza ores were depleted, and by 1891, the smelters in the district were shut down. Since 1906, the Eureka district has been worked sporadically by numerous companies (Roberts and others, 1967).

The irregular replacement deposits in the oxidized zone above the water table have yielded the major production thus far. The principal minerals are cerussite, anglesite, mimetite, plumbojarosite, limonite, calamine (hemimorphite), wulfenite, and smithsonite. Sulfide bodies, located at or below the water table were productive locally in deeper workings. The principal minerals in these deposits are pyrite, arsenopyrite, galena, sphalerite, chalcopyrite, molybdenite, and tetrahedrite (Roberts and others, 1967).

Lone Mountain District

The Lone Mountain district is located on the north flank of Lone Mountain in T. 20 N., R. 51 E. Initial claims were filed in 1920, but production was small until 1942, when a high-grade smithsonite ore was discovered on the Mountain View claim. The ore is in brecciated dolomite of the Devonian Devils Gate Limestone. It is localized at the intersections of two sets of faults. Total production from the mine was over $750,000 (Roberts and others, 1967). The mine has been closed since 1965.

The ore minerals are secondary smithsonite, zincite, hydrozincite, minor cerussite, malachite and azurite. Sphalerite, galena, chalcopyrite, and pyrite, probably primary, are present locally (Roberts and others, 1967).

Whistler Mountain Area

The Whistler Mountain area is dotted with bulldozed trenches and small exploration pits, which are developed on quartz and calcite veins. Prospect pits are especially abundant in the vicinity of the outcrops of Lone Mountain Dolomite in Diamond Valley; on the western flank of Whistler Mountain; and on Whistler Mountain. The Vinini Formation in section 15, T. 20 N., R. 52 E., was extensively prospected and staked, but no development work has been done. An exploratory adit was driven into a breccia zone on the south side of the west portal of Devils Gate, but apparently no ore was found and the prospect was abandoned. Records at the county court house indicate that much of the area flanking Whistler Mountain has been recently claimed.

Geothermal(?) wells were recently drilled in section 26, T. 21 N., R. 52 E., and section 15, T. 20 N., R. 52 E. However, no information about these wells is available from the Bureau of Land Management, the government agency responsible for this area.

SUMMARY AND GEOLOGIC HISTORY

General

During Early to Middle Paleozoic time, north-central Nevada was part of the large, subsiding Cordilleran geosyncline (Roberts and others, 1972). This geosyncline was composed of three major facies that trended northeast, roughly parallel to the border of the craton in eastern Utah (Roberts, 1969). Sedimentation in north-central Nevada, at this time, was miogeosynclinal.

Miogeosyncline

Cambrian sediments were deposited in a shallow shelf environment, characterized by Archaeocyathid bioherms and algal stromatolites (Suek and Knaup, 1979). Subsidence was slow. The shallow water environment produced limestone, quartzic-sandstone, and dolomitized limestone. In the Middle Ordovician, sedimentation was occasionally interrupted by transgressive and regressive seas affected in part by orogenic activity to the north (Dunham, 1979; Willden, 1979). The fluctuation in sea level allowed vast, subaerial sand deposits to form over much of the area. Subsidence continued at a moderate rate throughout this period. During the Silurian, shallow shelf conditions returned and were greatly extended over much of western Utah and eastern Nevada. This period was marked by abundant reef growth (Stokes, 1979). The Devonian miogeosyncline was marked by maximum deposition of sediments which gradually changed from dolomite to limestone. In central Nevada, carbonate banks were superimposed on those of the preceding Silurian (Stokes, 1979). During the Middle to Late Devonian, the miogeosyncline was locally uplifted and started to produce clastic sediments (Nolan, 1974).

Transitional

Transitional Ordovician sediments were deposited just west of the carbonate banks, and consisted of claystone, shale, chert, limestone, sandy limestone, and quartzite (Smith, Jr. and Ketner, 1975a). Silty dolomite and dolomitic marl were deposited in the deeper water basinal facies of Silurian and earliest Devonian time. Limestone debris flows, turbidites, and an outerbasinal limestone were also present (Suek and Knaup, 1979). Devonian rocks consisted of limestone, sandy limestone, chert, and interfingered westward with siliceous beds of deeper water origin.

Eugeosyncline

During Cambrian time, siliceous rocks with interbedded volcanics were generated in the eugeosyncline (Stokes, 1979). Ordovician sediments were laid down in subsiding basins west of the carbonate banks, and consisted of black shale, chert, quartzite, greenstone, mudstone, and deep-sea, pillow basalts (Smith, Jr. and Ketner, 1975a; Wrucke and others, 1978). Subsidence in Silurian time lessened, and sediments that were deposited consisted of deep-sea basalts, cherts, and siltstones (Stokes, 1979). Early Devonian age sediments were siliceous mustones, chert, shale, dolomite, and minor limestone, sandy limestone, and calcareous sandstone. These Devonian sediments marked the close of the eugeosyncline by the Antler Orogenic belt (Smith, Jr. and Ketner, 1975a).

Antler Orogeny

This orogeny began in Middle or Late Devonian time and continued sporadically until Middle Pennsylvanian time (Nolan, 1974). During initial movement, east-west compressional forces developed and structurally weakened portions of the crust (Spengler, 1979). These forces also formed a large, north-northeast trending geanticline west of Whistler Mountain, that began to supply debris to troughs to the east and to the west. Continued compression of the crust was eventually relieved by the formation of the Roberts Mountains thrust system. This thrust system brought the siliceous eugeosynclinal sediments eastward and southeastward of the carbonate sediments of the miogeosyncline. During this movement and uplift, fine to coarse clastic debris shed off of the advancing thrust system (Roberts and others, 1967). As the thrust system moved, occasionally blocks of carbonate rocks were incorporated in the thrust system. One of these blocks became the brecciated hill in section 15, T. 20 N., R. 52 E. Continued movement of the thrust system resulted in the overriding of earlier coarse Mississippian clastics.

Late Paleozoic Movements

From Middle Pennsylvanian to Permian time, only minor sporadic uplifts occurred which supplied limited amounts of debris to the surrounding shallow seas. The Sonoma orogeny of western Nevada did not affect the Whistler Mountain area.

Whistler Mountain

Emplacement History

Whistler Mountain (Armstrong, 1970) was emplaced 152 ± 3 m. y. ago, and is one of a large group of quartz-monzonite and granodiorite plutons that were emplaced in north-central Nevada in Jurassic time (McKee and Silberman, 1970). According to Spengler (1979) emplacement of these igneous bodies occurred along major structural zones of weakness associated with past deformation.

Textural and mineralogical evidence indicate that prior to emplacement, and at depth, the magma of Whistler Mountain was fluid and contained large, synneusis twins of plagioclase. After crystallization of these twins, this phase was terminated by a change in the cooling rate, which was probably related to upward movement of the magma. During this time a second generation of small, non-synneusis twinned plagioclase laths formed. Some of these crystals occur in aligned trains, which appear to be related to the upward movement of the magma. This feature is present only locally and then only in the finer-grained, marginal facies of the pluton. Plagioclase continued to crystallize incorporating quartz and opaque minerals in the outer rims of some phenocrysts.

Rare euhedral crystals of orthoclase indicate that some formed during the crystallization of the synneusis twins and continued to crystallize until the final stages of magma crystallization. Some large euhedral crystals of quartz indicate that crystallization of this mineral may have started at the same time or shortly after, the crystallization of the synneusis twins. Such crystals occur in the marginal facies of the pluton and in the sills. Crystallization of non-poikilitic quartz followed and was in turn followed by the crystallization of late stage poikilitic quartz.

Biotite and primary muscovite formed with quartz and orthoclase and continued to crystallize throughout much of the pluton's crystallization history. Magnetite only occurs in the margins of some plagioclase phenocrysts, and within quartz grains and, therefore, is a late stage mineral in these rocks. Apatite shows similar relationships and is also a late stage mineral. Zircon, which occurs primarily in quartz, appears to have crystallized early.

Emplacement

Whistler Mountain was emplaced at less than 10,000 ft, as an epizonal laccolith (Armstrong, 1966), along a possible erosional or thrust contact between Mississippian and Devonian sediments and/or the Vinini Formation. Emplacement did not produce a metamorphic aureole. Evidence of stoping is rare.

Border zones consist of very fine to cryptocrystalline porphyritic rocks which indicate rapid crystallization. The south end of the pluton is characterized by numerous sills which preferentially invade the Paleozoic sedimentary rocks along contacts and bedding planes. Such features are absent at the north end of the pluton where the contact is sharp. While the central portion was still hot and somewhat plastic, cooling joints began to form. During this period hot, boron-rich fluids and/or gases ascended along the early cooling joints. The boron reacted with the feldspars and biotite to form tourmaline (schorlite). Tourmaline was deposited on joints and sealed some of them. The same processes gave rise to disseminated tourmaline spots and nodules. Some late stage alteration of the feldspars may have occurred at this time. Tourmalization of the pluton was followed by the invasion of silica-rich fluids that gave rise to quartz veins and dikes. Calcite and hematite veins and veinlets may be a very late stage hydrothermal feature or be related to weathering.

Basin and Range Orogeny

During the Late Cretaceous or early Tertiary time north-central Nevada was subject to folding and normal faulting (Roberts and others, 1967). In Oligocene time, the Eureka area became a very active volcanic center and large amounts of primary pyroclastics were deposited. Large ignimbrite sheets were also developed and covered over one hundred