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July 25, 1980

Geology Manager
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Dear Sam:

Enclosed you will find the final report for the Ikpikpuk No. 1 test well. This well was drilled as a deep structural test on the north side of the Ikpikpuk Basin and to gain stratigraphic data for that part of the National Petroleum Reserv, Alaska. The well spudded on November 28, 1978 and was suspended for the summer after reaching a total depth of 14,210' and setting a 7" liner to 14,208'. Drilling was resumed on January 7, 1980 and a total depth of 15,481' was reached on February 12, 1980. The well tested a complete section from the Nanushuk Group to the Mississippian Endicott.

No significant hydrocarbon zones were found and two drill stem tests failed to recover hydrocarbons at a rate which would be commercial.

For the purpose of this report I have in part made use of the interim report prepared by Mr. David B. Young.

Richard V. Nelson Jr.

Richard V. Nelson, Jr.
Consulting Geologist

GEOLOGICAL REPORT

USGS/NPR-A

(HUSKY OIL, OPERATOR)

IKPIKPUK NO. !

1306' FNL, 785' FEL, Sec. 25,

T13N, R10W, UM

National Petroleum Reserve-Alaska

North Slope, Alaska

by

Richard V. Nelson, Jr.

FORMATION TOPS

Formation	Prognosis	Sample	Paleo	Electric Logs Measured	Subsea
Colville Grp.	1st sample @ 100'		100'	100'	-48'
Nanushuk Grp.		160'			
Torok Fm.	3,875'	3,800'	3,545'	3,750'	-3,698'
Pebble Sh.	7,341'	7,240'	7,240'	7,237'	-7,185'
Kuparuk		7,428'		7,432'	-7,380'
Kingak Fm.	7,350'	7,465'	7,640'	7,640'	-7,588'
Sag River SS	9,921'	9,945'	9,840'	9,844'	-9,792'
Shublik Fm.	9,960'	10,140'	10,180'	9,898'	-9,846'
Sadlerochit Grp.					
Ivishak Fm.	10,609'	10,500'	10,570'	10,443'	-10,391'
Kavik Mbr.		11,100		11,098'	-11,046'
Echooka Fm.		11,296'	11,290'	11,290'	-11,238'
Lisburne Transit.			11,380'	11,446'	-11,394'
Lisburne	11,515'	11,704'	11,620'	11,673'	-11,621'
Endicott Grp.	13,640'	14,845'	14,850'	14,840'	-14,788'
Metamorphics	15,921'	15,320'		15,320'	-15,268'

CONVENTIONAL CORES

Core #	Interval	footage cut/rec/%	General Lithology
1	2930'-2960'	30'/30'/100%	Siltstone and claystone
2	3784'-3812'	28'/28'/100%	Medium gray shale
3	5690'-5700'	10'/10'/100%	Shale with silt laminations
4	7132'-7143'	11'/11'/100%	Shale with silty sandstone
5	7368'-7378'	10'/ 9'/ 90%	Dark gray-brown shale
6	7491'-7501'	10'/10'/100%	Dark gray-brown shale
7	10270-10300'	30'/30'/100%	Fossilif. Limestone and shale
8	10619-10649'	30'/30'/100%	Sandstone, very fine, tight
9	10815-10842'	27'/27'/100%	Sandstone, very fine, hard tight
10	11108-11135'	27'/27'/100%	Shale, dark gray, hard
11	11718-11733'	15'/15'/100%	Limestone, biocalcarenite, pel, tt
12	12743-12753'	10'/10'/100%	Limestone, biocalcarenite
13	14971-14986'	15'/15'/100%	Red shale, siltstone and sandstone
14	15421-15424'	3'/ 1'/ 33%	Metamorphic quartzite
15	15461-15462'	1'/ 0'/ 0%	
16	15463-15469'	6'/ 4'/ 67%	Solid xln meta-quartzite

ELECTRIC LOGS

Run No. 1 521'-100'
DIL/GR/SP, BHC Sonic/GR/TTI

Run No. 2 2603'-521'
DIL/GR/SP, BHC Sonic/GR/TTI

Run No. 3 9904'-2603'
DIL/GR/SP, BHC Sonic/GR/TTI, HRD, FDC/CNL/GR/CAL (9908'-2206')
CST's, Velocity Survey 250'-9854'

Run No. 4 14202'-9873'
DIL/GR/SP, BHC Sonic/GR/TTI, HRD Dip, CST's, FDC/CNL/GR/CAL,
Velocity Survey 2880'-14210'

Run No. 5 15400'-14208'
DIL/GR/SP, BHC Sonic/GR/TTI, FDC/CNL/GR/CAL, HRD, Temp 2(100'-15435'),
Velocity Survey 3750'-15400'

ABSTRACT

The Ikpikpuk Number 1 test well was drilled over the course of two drilling seasons, 1978-1979 and 1979-1980. It spudded November 28, 1978 and was suspended for the summer of 1979 after setting a liner to a depth of 14,208. The section at that point had been tested down to the top of the lower limey unit of the Lisburne. Operations resumed on January 7, 1980. The well penetrated an additional 640' of the Lisburne and then the Endicott Group and reached a total depth of 15,481 in a metamorphic quartzite.

This well was programmed as a deep test of near basement fault closure and to gain stratigraphic data for the Ikpikpuk Basin. The sections where reservoir quality formations were expected were: Nanushuk, Kugrua Sand (within the Kingak Formation) and possibly the Ivishak. Any trapping at these levels would have had to have been stratigraphic in nature. The Lisburne and Endicott sections were hoped to also contain reservoir quality units and a structural/fault closure was expected at the lower levels.

No good shows of oil or gas were encountered while drilling and all intervals on the electric logs were interpreted as having high water saturations. Two drill stem tests were run on the two best zones and both recovered gas a too low a rate to measure. The well does however provide valuable stratigraphic information.

STRATIGRAPHY

LATE CRETACEOUS - Possible Colville Group

Samples collected from the base of the conductor pipe (100') to a depth of 160' contained Foraminifera which indicated a Late Cretaceous Cenomanian age. (Anderson, Warren & Associates, Inc. Zone F-8; see Appendix A) Based on Palynological data the interval from 100' to 550' fell within the Cenomanian A.W.A. Zone P-M16 (See Appendix B).

The sediments in this interval consisted of interbedded shaly sands; carbonaceous, gray, argillaceous siltstones; Gray, silty, carbonaceous, water soluble claystones; and thin lignite and coal beds. Mostly of marginal marine deposition, the upper 60' may represent the base of the Colville Group sediments. Age dates for this interval span the boundary between Coleville and Nanushuk Groups and a distinction between the two is difficult.

The only indications of hydrocarbons which were noted during drilling were methane spikes which appear to be associated with the coals.

EARLY CRETACEOUS - Nanushuk Group

Dates based on both Foraminifera and Spores from the interval 550' to 3485' were F-9 and P-M17, Middle to Late Albian. This puts the section well within the Nanushuk Group. Based on electric log correlations, the base of the Nanushuk Group sediments is picked at 3750'.

Sediments in this interval were generally of marginal marine to outer neritic in nature and probably were lain down in alternating transgressive and regressive cycles. Lithologies consisted of: gray, water soluble claystones; gray, carbonaceous siltstones; light gray, fine to occasionally coarse grained sandstones; with minor thin coals and siderite beds or concretions. Net clean sand for the interval is about 300'. In general the upper part of the section is coarser than the lower.

While drilling, minor methane gas was noted, mostly associated with the thin coals. Minor amounts of sample fluorescence and a slight cut fluorescence (but with no stain or gas associated) were noted in sands between 1210' and 1300'.

EARLY CRETACEOUS - Torok Formation

The top of the Torok Formation was picked at 3750' on the basis of electric log correlations. The base of the Torok Formation is placed at the marked change to the distinctive dark shale of the Pebble Shale Formation at 7237'. Foraminifera found in the samples from this interval were identified as being in the zone F-10 (Late Aptian to Early Albian) from 3485' to 5180' and F-11 (Aptian) from 5180' to 7240'. Based on spores the interval from 3440' to 7360' was classified as P-M18 (Aptian to Early Albian).

Down to 6000' the lithology is dark gray, micaceous shale with pyrite inclusions and minor carbonaceous material and thin beds and laminations of siltstone. The lower part of the Torok from 6000' becomes silty to sandy with gray-brown, fissile shale and medium to dark gray, firm shale. Sands are dirty and using a cut-off of 60 API Gamma Ray Units there was a net of about 170' of sand.

Economic Potential

Sands between 6000' and 6330' are generally silty and shaly with no shows of oil or gas.

Sands between 6675' and 6820' are light gray, fine to medium grained, quartzose, poorly sorted, sub-rounded to sub-angular and in part filled with white clay. Fair SP Log character is developed in the sands. No visible hydrocarbon indications were observed. Gas in the drilling mud increased to 104 units at 6820' with a chromatographic breakdown of 17,300 ppm C_1 and 550 ppm C_2.

The interval from 6872' to 6978' consists of light gray quartz sandstone with varying amounts of clay filling. Good gassy odor and bright yellow fluorescence were noted throughout the interval though there was no visible staining. Maximum gas in the drilling mud was 1210 units of total gas consisting of 22,000 ppm C_1, 1500 ppm C_2, 4000 ppm C_3, 1020 ppm C_4 and 81 ppm C_5. Drill stem test number two tested perforations from 6877' to 6923' and indicated generally tight formation characteristics with a gas flow rate too low to measure. As this was the best zone in the Torok, based on both observations while drilling and electric log analysis, no other tests were run in the Torok Formation.

From 6978' to 7237' interbedded sandstone and gray-brown shales occur. The sandstones are light gray to gray, very fine to fine grained with water soluble clay as a matrix material. No visible oil staining was noted although a bright yellow-white fluorescence was observed on fresh breaks. Maximum gas recorded was 91 units.

EARLY CRETACEOUS - Pebble Shale

The top of the Pebble Shale is a good pick with agreement between samples, paleo data and electric logs and occurs at 7237'. The top of the formation shows up as highly radioactive on the Gamma Ray tool. Only very thin and shaly sand stringers occur within the Pebble Shale. These sands do not develope an SP response. The bulk of the unit consists of very dark gray to black, micaceous, splintery shale having a slight brownish cast and with characteristic "floating" grains of well rounded, frosted to polished quartz grains throughout the shale.

The only hydrocarbon indications were a maximum gas level in the mud of 120 units total gas and 22,000 ppm C_1, 1200 ppm C_2, 780 ppm C_3, 170 ppm C_4. No visible staining was observed but a slow, streaming, bright yellow cut fluorescence was observed.

Kuparuk River Sand

Also known as the "Pebble Shale Sand" the unit lies at or in the base of the Pebble Shale Formation and was topped at 7432'. It is a transgressive marine sand. The sand is white to light brown, very fine grained, sub-angular to angular, slightly friable with rare glauconite. This unit is the basal member of a transgressive sequence which began in Late Jurassic time and continued into the Early Cretaceous Neocomian. The marine shales underlying the unit are Early Cretaceous to Late Jurassic.

Economic Potential

Kuparuk River Sand log porosities average 11% with high water saturations. A maximum gas level of 125 units and 22,000 ppm C_1, 1000 ppm C_2, 350 ppm C_3 and 100 ppm C_4 was recorded. About 10-15% of the sample from 7440' to 7445' exhibited a yellow sample fluorescence.

Drill stem test number one tested perforations from 7446' to 7472'. The only recovery from the formation was gas at a rate which was too little to measure. The test confirmed what the electric logs had indicated.

EARLY CRETACEOUS to JURASSIC - Kingak Formation

Marine shales directly underlying the Kuparuk River Sand and beginning at 7640' were dated as Early Cretaceous, Neocomian (P-M20) based on Palynology and Late Jurassic, Tithonian to Early Cretaceous, Valaginian (F-13 to F-15) based on Foraminifera. The base of the Kingak Formation based on electric log correlations was placed at 9844', which agrees well with micropaleo data. The Foraminiferal zonations for the Kingak were: 7690' to 8190' Late Jurassic Oxfordian (F-16); 9180' to 9600' Early to Middle Jurassic (F-17 to F-18); 9600' to 10,110' a mixed assemblage indicating F-18 with an incomplete Late Triassic F-19 assemblage. This last interval spans the boundary between the Kingak and Shublik Formations. Based on spores and pollen the A.W.A. zonation for the Kingak is: 7480' to 7840' Early Cretaceous, Neocomian (P-M20); 7840' to 8290' Late Jurassic Kimmeridgian to Tithonian (P-M21); 8290' to 9100' Late Jurassic, Oxfordian (P-M22); 9100' to 9730' Early Jurassic (P-M23).

The Kingak Formation from 7478' to 9035' consists principally of dark gray to black marine shales which are commonly micaceous, silty, fissile, glauconitic, pyritic, slightly fossiliferous and with occasional floating quartz grains and siderite concretions.

From 9035' to 9103' a sandstone unit known locally as the Kugrua Sand is present. This is the age equivalent (Basal Oxfordian) to the thick, porous, massive sands that were found in the Kugrua No.1 test well at a depth of 8713' and at South Meade No.1 at a depth of 7878'. This sand is gray to light gray, very fine grained, silty, well sorted and with rare glauconite and pyrite. Samples and electric logs indicate the sand to be shaly with low permeability. At both Kugrua and South Meade severe lost circulation occurred in this zone but only to a much lesser extent in this well.

Lithology from 9103' to 9624' consists of dark gray, black and dark gray-brown marine shales. Rare glauconite and floating quartz grains were noted. Parts were silty to sandy with some thin stringers of siltstone.

From 9624' to 9672' a sandstone bed is present. This sandstone is medium gray-brown, very fine grained, silty, slightly argillaceous, subangular, well sorted, with low porosity. A very slight cut was obtained from these samples.

The interval from 9672' to the base of the Kingak at 9844' consists of marine shales interbedded with siltstone. The shale is dark gray to dark brown, slightly micaceous, fissile to splintery, pyritic and rarely fossiliferous.

Economic Potential

The sand interval from 9035' to 9103' (Kugrua Sand) is shaly and tight in this well. The maximum gas recorded was a total gas of 53 units consisting of 5400 ppm C_1, 800 ppm C_2, 350 ppm C_3 and 120 ppm C_4. Though a very slight cut was obtained, no staining was observed.

The lower sandy interval from 9624' to 9672' is also shaly and tight. No visible staining was observed but a very slight cut was noted. Maximum total gas recorded was 120 units (16,000 ppm C_1 only). No other potential reservoirs were present in the Kingak Formation.

EARLY JURASSIS TO TRIASSIC - Sag River/Shublik Formations

The top of the Sag River is picked at the top of the sand. In the Ikpikpuk Number 1 test well this occurs at 9844'.

Foraminifera, as indicated above, did not give an exact top for zone F-19 because of contamination from above and an incomplete assemblage. The interval from 10,110' to 10,390' does have a good representation of the zone F-19 (Triassic) assemblage. Palynology data for this entire interval lacked the basic determining members.

The sand interval of the Sag River is from 9844' to 9898', though the lower 30' is quite shaly. It is dark gray-brown, very fine grained, silty, subangular, well sorted, hard, slightly calcareous with rare glauconite. There is no evidence of unconformity with the Kingak or Shublik but the character of the Sag River is not that of the barrier bar and beach complex that are found in wells to the north of Ikpikpuk, i.e., East Teshekpuk No.1, East Simpson No.1, Kugrua No.1. The depositional environment at this location is interpreted as having been near-shore marine giving interbedded siltstone, sand and shale.

No significant shows of oil or gas were observed in these sands and overall reservoir conditions are poor.

The break between the Sag river and the Shublik is poor but the lower Shublik and the contact with the underlying Sadlerochit Group appears normal. The top of the shublik is placed at 9898' on the basis of electric log character.

The Shublik Formation consists of near-shore deposits of marine, calcareous shale with common pelecypods and crinoids; thin dark gray to tan, fossiliferous limestones with black phosphate pellets; and thin siltstone beds with rare glauconite, pyrite and carbonized wood fragments.

No possible reservoirs or zones giving high gas readings were encountered in the Shublik.

PERMO-TRIASSIC - Sadlerochit Group

Ivishak Formation - The top of the Ivishak is picked at 10,443' on electric logs, the top of the sandstone. Foraminiferal data from 10,390' to 10,570' indicates a Triassic (F-19 to F-20) age. An age could not be determined for this interval down to 10,740' based on palynology.

The interval from 10,443' to 10,602' is light gray to tan, very ine grained sandstone interpreted to be pro-delta to near-shore marine. It is quartzose, silty, and siliceous with minor occurrences of black phosphate pellets, rare glauconite and having finely disseminated pyrite. The sandstone is interbedded with brownish gray flakey shale and brownish gray firm siltstone.

From 10,602' to 10,732' a clean bioturbated quartz sand is developed which is thought to represent deposition in a prograding delta. The lithology is quartz sandstone, fine to medium grained at the top decreasing in grain size to very fine grained at 10,620', and consisting of white to clear quartz, well compacted, in part siliceous, wubrounded to rounded, well sorted, commonly bioturbated; with thin horizontal shale partings and rare siliceous nodules or clasts. The best log porosity is developed between 10,610 ' and 10,670', averaging 15%. The sand calculates to be water bearing.

Approximately 200 barrels of mud were lost to the formation at 10,651'.

The interval from 10,732' to 11,098' was dated as Permo-Triassic (F-20) based on Foraminifera. Palynology on the interval 10,740' to 11,830' can only say it is probably undifferentiated Permian to Triassic.

From 10,732' to 11,098' deposition is interpreted to be continental to marginal marine. Red to pink silty shale and siltstone are common and are interbedded with carbonaceous sandstone beds representing probable bar or distrubutary channel deposits. Two sand units are present in this interval. The first from 10,810' to 10,847' consists of light gray, very fine to fine grained, siliceous sandstone with a middle section of fine to medium grained, poorly sorted, pebbly, varicolored, slightly argillaceous, carbonaceous, siliceous sandstone with thin shaly partings and shale clasts. The second interval from 10,948' to 11,001' consists of sandstone which is red and gray, fine to very fine grained, slightly friable, subrounded to subangular, clear to white, orange and pink quartz grains. It is carbonaceous and in part siliceous. Maximum log porosity developed in these sands is 14% with high calculated water saturation. A loss of 400 barrels

of mud occurred at 11,001' but may have gone into the zone above.

Kavik Member - Topped at 11,098' this represents a change back to marine depositional conditions. Lithology of the Kavik is dark gray brittle shale with thin siltstone stringers and rare carbonized plant fragments.

Echooka Formation - Topped at 11,290', the Echooka Formation is thought to have been deposited as marine to non-marine by a transgression to the north. Lithology is dark green, shaly, siliceous, glauconitic, very fine grained, subangular quartz sandstone with interbedded gray siltstone and dark gray-green, dark gray and red mottled shales. The best porosity indicated on the neutron porosity log is only 6% and was from 11,321' to 11,334'.

Maximum gas in the mud while drilling the Echooka was only 35 units, which occurred at about 11,325'.

PERMIAN - MISSISSIPPIAN - Lisburne Group

Below the base of the Echooka at 11,446' and above the top of the actual massive limestone of the Lisburne is a section called here the "Lisburne Transitional". This shallow marine carbonate-clastic depositional regime as seen at Ikpikpuk is very similar to that found at Inigok No.1. This section is composed of interbedded gray, tan, gray-brown, chemical limestones; dark gray, silty, calcareous, micaceous shale and dark gray siltstone with rare fossils. The actual top Lisburne is picked at 11,673'. Foraminifera from the interval from 11,380' to 11,620' indicate an Early Permian zone F-21 age.

Lisburne "Upper Limestone Unit" - Based on electric log correlations the top of this unit is placed at 11,673'. These sediments were probably deposited on a shallow marine shelf which was mostly clastic starved but with occasional shale and siltstone beds. The carbonates are primarily clean bioclastic and allochemical limestone composed of crinoids, bryozoans, foraminifera, brachiopods, spines, oolites and pellets with calcspar and occasionally micritic cement. It is generally recrystallized to the point that fossil grains are indistinct to being only ghosts. The rare occurrence of dolomite and lack of evaporites, coupled with the recrystallized tight limestone points to an environment of carbonate deposition with unrestricted waters.

Samples from 11,620' to 11,830' contain foraminifera indicative of zone F-21 age. The interval from 11,830' to 12,480' is indicated to be no older than zone 21. A call of Mamet's zone 20 is made at 12,930' (Lower Pennsylvanian). The section from 13,450' to 13,760' is thought to be Z-18 to Z-19. The dolomite unit between 13,760' and 14,000' is poorly fossiliferous but should represent Z-17 to Z-18 age deposits. The section from 14,000' to 14,850' represents Z-14 to Z-16 age rocks.

MISSISSIPPIAN - "Dolomite Unit" - The top of the dolomite is placed at 13,760'. This unit consists of basically the same type of limestone encountered above but with thin beds of dolomite. No evaporites occur with the unit and as such it is thought to represent a period of carbonate deposition in which the waters were somewhat restricted,

although not to the point of being a "sebka". Slight pinpoint to small vug porosity occurs in the dolomite, but no effective permeability exists. The maximum log porosity developed in the dolomite unit was 6% from 13,784' to 13,788'.

"Lower Limey Unit" - Based on the change to lime packstone and on paleontological evidence the section from 14,000' to 14,840' is thought to represent the Lower Limey unit of the Lisburne. Down to 14,460' carbonates dominate with interbedded medium to dark gray limestone and medium gray, finely crystalline dolomite. Considerable secondary silicification has occurred through this part of the Lisburne. From 14,460 downward the section contained far more detrital material with dark gray argillaceous siltstones and occasional sandstones interbedded with fine limestones and dolomites.

Lisburne carbonates were very tight throughout with log porosities in the range of 0-3%. Probable depositional environment was that of a shallow, low energy shelf. These do not normally produce carbonates with good primary porosity. Post-depositional changes, including considerable silicification, have limited secondary porosity.

Oil and gas indications: No significant indications of gas or oil were noted in the Lisburne Group either while drilling or on electric logs. Maximum gas in the mud while drilling occurred at 11,839' with 335 units of total gas and chromatograph readings of 88,900 ppm C_1, 1500 ppm C_2, and 25 ppm C_3. These gas levels occurred in a tight section with no reservoir potential.

MISSISSIPPIAN - Endicott Group

The section from 14,840' to 15,320' was marked by interbedded red sandstones, argillaceous red siltstones and red shales. General lithology suggests that this is probably Itkilyariak or possibly Kekiktuk equivalent. An increase in dark carbonaceous shale and coal below 15,310' with possibly some anhydrite would indicate probable Kekiktuk.

Hydrocarbon Potential No shows of gas or oil were observed while drilling this section with even the coals giving poor gas response. Electric logs confirmed the lack of hydrocarbons as well as the absence of reservoirs.

PROBABLE PRE-MISSISSIPPIAN

"Basement" in this well consists of crystalline quartz and occurred from its top at 15,320' to the total depth of the well at 15,482'. This formation is extremely hard. Three cores were attempted with poor recoveries.

Thin section petrography and x-ray analysis of samples of core 14 at 15,421' were performed by Dr. H.E.Enlows at Oregon State University (Appendix C). It was described as consisting of quartz crystals and clasts having a cataclastic texture and a fine groundmass of *Wilkeite*, a somewhat uncommon metamorphic mineral first identified in contact

metamorphics in Californis where it was associated with garnets and other metamorphic minerals.

The grade of metamorphism and the abrupt change suggests a Pre-Mississippian age but no farther correlation was attempted.

TESTING

At the completion of the drilling and logging of the Ikpikpuk No.1 test well the hole was plugged back in stages and two drill stem tests were run as a final check of the only two zones with any hydrocarbon potential.

Test number 1 was through perferations from 7446' to 7472'. The test was given an initial flow period of 30 minutes. Gas did not reach the surface until 58 minutes after the test tool was first opened. Flow rates were too low to measure.

Test number 2 was through perferations from 6877' to 6923'. Gas did not reach the surface until 48 minutes into the final flow period and was too low a rate to measure.

With the completion of the drill stem tests the well was considered to have been fully evaluated and was plugged and abandoned as a dry hole.

Appendix C

Core No. 14 Petrographic Report

Department of Geology Oregon State University Corvallis, Oregon 97331 (503) 754-2484

Feb. 16, 1980

REPORT ON THREE ROCK SAMPLES SUBMITTED BY:
Sam Hewitt, Husky Oil NPR Operations Inc. Received Feb. 8, 1980

Procedure.

The three samples, labeled Ikpikpuk #1, 15421.0', 15421.2' and 15421.3', were obviously three different samples from the same rock unit so the description below is a composite of the three. Petrographic and X-ray diffraction analyses were used to determine the texture and check the mineral content.

Macroscopic.

The rock appears to be a breccia consisting of light gray, angular quartz clasts of widely varying size (3 cm to a fraction of a millimeter in diameter) in a very light gray, finely crystalline matrix. Many small pyrite grains can be seen scattered through the finely crystalline matrix.

Microscopic.

The brecciated or "cataclastic" texture is readily visible microscopically and appears to be of tectonic origin, perhaps shearing during shallow metamorphism. The quartz clasts vary dramatically in size and practically all are markedly angular. Veinlets of the matrix material are at places found traversing the quartz clasts.

Quartz Clasts. The quartz clasts may be:
(1) Single crystal grains one millimeter or so in diameter, angular to subangular, suggesting, in some instances, broken rounds. Single crystal grains are rare.
(2) Polycrystalline grains, the various polycrystalline units joined in sutured contact. The crystalline units are often large, up to one millimeter across, and in some grains are elongate parallel to a common direction. This type quartz clast are the largest and form the majority of the clasts.
(3) Chert or fine polycrystalline grains.

Matrix. The matrix consists chiefly of a finely crystalline mass of a mineral identified by X-ray analysis as Wilkeite ($(Ca_5(P,S,Si)O_4(OH,CO_3))$), minor quartz as small anhedral grains and tiny pyrite crystals.

The matrix was generally featurless, but in a few instances darkened in certain areas to form "ghosts" of grains a millimeter or so in diameter or to form a "streaky" texture, perhaps generated by flow.

Point Count. Three thin sections were made, one from each sample, and a composite point count was made to obtain some idea of the mineral abundance. The result is given below.

Wilkeite	- 1329	points	68%
Quartz	- 610	"	31
Pyrite	- 11		0.6
Calcite	- 5		0.3
Muscovite	- 3		0.1
	1958		100.0

X-Ray Diffraction

A diffractometer run from 5 - 60 two theta was made on the matrix. Major peaks and the corresponding peaks for wilkeite and quartz are listed below.

Diffractometer Trace		Wilkeite		Quartz	
dA	Intensity	dA	Intensity	dA	Intensity
8.05	W	8.14	60		
4.25	W			4.26	35
3.86	W	3.85	10		
3.44	VS	3.45	70		
3.34	VS			3.34	100
3.16	S	3.18	10		
3.06	S	3.06	30		
2.79	VVS	2.80	100		
2.77	VS				
2.70	VS	2.70	90		
2.61	S	2.61	60		
2.51	M	2.51	20		
2.29	M				
2.24	S	2.24	80		
2.18	M				
2.06	M	2.06	10		
1.99	W	1.99	20		
1.93	VS	1.93	80		
1.88	M	1.88	30		
1.83	VS	1.83	80		
1.82	W			1.82	17
1.79	M	1.79	30		
1.78	M				
		1.76	50		
1.74	M	1.74	50		
1.72	S	1.72	50		
1.63	M	1.63	30		
1.60	VW	1.60	10		

Here reached 60 two theta and stopped the record.

The larger d spacing are often inaccurate so I discount the lack of precision in matching the 8.14 Wilkeite peak while the extra peaks of the record I cannot account for. However, the accuracy of the rest makes the identification unmistakeable.

Wilkeite

This somewhat uncommon mineral was first identified along with diposide, vesuvianite (idocrase), garnet, crestmoreite and blue calcite in the contact metamorphic marble at Crestmore, Riverside County, California. Subsequent occurrance have been of a similar nature. It is an intermediate member of a series extending from apatite to ellestadite and contains only 20% P_2O_5 as against 41-42% P_2O_5 for apatite. The chemical composition is usually given as $Ca_5(P,S,Si)O_4(OH,CO_3)$.

ORIGIN OF THE ROCK

The cataclastic texture, presence of broken rounds of quartz grains, coarsely recrystallized masses of what appears to have been chert and the abundance of the phosphatic rich metamorphic mineral Wilkeite and minor muscovite appear to be the major pieces of evidence. I suggest a metasediment.

The original sediment must have been cherty, phosphatic and calcium rich and contained some minor interbedded sandstone. Shallow metamorphism including shear along with increased temperatures would produce the rock we see.

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