MINING CALCITE CRYSTALS DURING WORLD WAR II

Lew Orrell

The ignominy of Pearl Harbor was but four months old. Yet, in the Spring of 1942 the somber ambiance of the passenger terminal at New York City's La Guardia airport already reflected the nation's transition from carefree peacetime to the grim purposefulness of wartime. Two men threaded a path toward each other through the imbroglio of travelers. A small, thin wafer changed hands and the recipient held it to his eye. Reaction was immediate and positive. With a fervent plea that more copies be supplied quickly, Navy Lieutenant Ballard returned to Washington to announce to the Fleet that a new aiming device was in the offing. Dr. Edwin Land returned to his laboratories at Polaroid to improve the device and to master the problems of supplying it. The military's Optical Ring Sight (ORS) program had been launched.[1]

When the Lieutenant held the wafer to his eye, he saw a series of concentric, colored circles which overlaid objects viewed through it. Because the circles appeared at optical infinity, their alignment with the target was unaffected by motion of the observer's head. Suitable encased in a metallic support, fitted with protective covers and filters, and aligned with the bore of a weapon, the wafer became the innovative ORS. Because it was simple, light-weight, inexpensive, and without electrical illumination, the ORS showed great promise as a practical means for improving the accuracy of gunfire.

The wafer consisted of layers of special optical materials which were laminated to a thin disk of optical calcite. By varying the nature and orientation of the layers and the thickness of the calcite disk, different reticle patterns could be achieved and the diameter of the innermost circle could be varied. This flexibility in design motivated searches by each of the armed service for suitable weapons with which to use it. Over the course of the next year or more, each of the services designed and tested at least one application; the Navy had several in development.

Most of the materials needed to make an ORS were readily available, the one exception being the vital wafer of optical calcite. About the size of a 50-cent piece and the thickness of the proverbial thin dime, the wafer weighed only a few ounces. Nevertheless, the wafers were very fragile so production seldom yielded more than two per pound of acceptable crystals. Thus, when orders for the ORS peaked at 90,000 units in 1943, they established a need for 45,000 pounds of optical calcite—an unprecedented amount. (NOTE: True optical calcite must be colorless and free of all internal defects. Suboptical calcite could have

slight coloration and minor defects at the edges of the crystal. Suboptical grade was acceptable for the ORS as it was at least 10 times more prevalent than true optical. Throughout this paper "optical calcite" and "calcite crystal" are used in place of "suboptical.")

Calcite (calcium carbonate) is more familiar under such names as limestone, Carrara marble, chalk, travertine, or Mexican onyx. These forms occur in massive blocks of sedimentary deposits of minuscule crystals or grains (polycrystalline calcite). Such calcite is essential to an industrial economy (power plants, sugar refineries, and paper manufacturers, for example are large users) and the United States consumes "hundreds of millions of tons" per year.[2]

Less commonly, calcite is found in narrow veins where it was deposited by hydrothermal action. On the rare occasions that this action occurred under appropriate geologic conditions, large, single crystals grew at the expense of the usual multitude of tiny ones. When conditions of growth were ideal, the resulting crystals are clear, colorless and free of cracks, bubbles, and twinning. These are known and prized as optical calcite (Iceland Spar). Because of Spar's strong birefringence it has been important as a light polarizer in scientific instruments. However, prior to World War II such applications consumed onlyl about 200 pounds per year, which was usually imported.[3]

As the Spring of 1942 wore into mid-summer, enthusiasm for the ORS among the military, especially the Navy's Bureau of Ordnance, grew stronger. Yet, its prospects for the future were bleak: 1) although the Navy ordnance division talked of a need for large numbers of the sights in the near future, they ordered only a few; 2) aside from a modest quantity of crystals sequestered at the National Bureau of Standards (which Polaroid quickly consumed),[4] there was no stockpile;[5] 3) there were no active domestic producers of optical calcite nor were there known deposits of sufficient size and quality to meet the projected need.

These factors might well have spelled the end of the ORS program had it not been for Edwin Land. Displaying a deep commitment to the war effort, he insisted that Polaroid establish sources for the crystals—even thought that put the company "further outside our field than even we care to contemplate."[6] Thus, optical calcite joined quartz, mica,[7] and fluorite[8] in a quartet of crystals that the war boosted from relative obscurity to strategic importance.

Land looked to researchers at Harvard University to assist technically Polaroid's staff of scientists and engineers. He recruited Professor Harry Berman, a mineralogist and consultant to the military's quartz crystal program. Harvard's mineral collection and Berman's informal national network of mineralogists and geologists soon flushed out two potential sources of supply, one in Montana and one in California. Each was owned by men with little or no knowledge of mining and no experience in the retrieval and processing of fragile crystals. However, the need was exigent so Berman urged them to recover crystals to sell to Polaroid.

The crystals from Montana had poorly delineated faces ("Montana potatoes" to Polaroid employees), whereas the ones from California were flat (basal) plates. As the vertical axis of the plate coincided with the optical axis of the wafers, the plates were easier to orient and process into wafers and were the preferred crystal shape.

Desultory, amateurish efforts in California in the four months following Berman's startup resulted in a slow beginning for the ORS program. At the same time, the military demands for sights were growing. The Navy pressured for more concrete evidence of large-scale production capability. Clearly, sight production depended on an adequate and reliable supple of optical calcite. In the meantime, Land placed crystal production in the hands of experienced mining men, Arnold and Robert Hoffman, and gave priority to the California location, the source of the preferred crystals.

Selection of the Hoffmans, who had outstanding credentials, gave credibility to the Polaroid calcite venture as a serious mining effort. Graduates of Harvard University (Robert with four technical degrees), they had served an arduous apprenticeship prospecting in the Canadian bush.[9] Discovering good gold-producing properties in the emerging Ontario mining districts enabled them to open a consulting office on Fifth Avenue in New York City.[10] By the time of their

recruitment by Land they were recognized internationally as successful mine developers.

Arnold, who preferred administration, spent the days of early October, 1942, forming a corporation (Calcite Operators, Inc.) to contract with Polaroid, while Robert, the engineer, went to California and surveyed the Palm Wash (or Hilton) deposits. The field was located at the edge of the Colorado desert, west of the Salton Sea. It was at the edge of the Borrego Badlands and in the foothills of the Santa Rosa Mountains. About 10 mines from the nearest road and 40 miles from Indio, the nearest community of significant size, the deposits lay in barren, arid, rugged terrain in an isolated and harsh environment.

On October 15, Robert sent from the field a preliminary report stating that the "Palm Wash deposits are by far the most important potential source of optical calcite which we have seen." They "might well provide all the optical material needed." He emphasized the need for "intensive development, coupled with close engineering and mineralogical supervision...") Almost prophetically he predicted "great difficulties in working the Palm Wash deposits" which made finding personnel adequate for the task a "paramount problem." Only slightly secondary were the "lack of road, lack of water, lack of shelter, and lack of equipment."[11]

Four days later, Hoffman submitted the supporting details. Again he emphasized the inaccessibility and isolation of the location of the deposits and the absence of water. He suggested digging wells at the base of the mountain or drilling deep wells nearer the workings. He also noted the absence of shrubs and trees which meant that fuel for cooking and heating would have to be packed in. The report continued by describing the geology and extent of the calcite occurrences and pointing to the evidence for hydrothermal deposition. He discussed the mining procedures to be used to recover the crystals, noted that they were most likely to be found in vugs (pockets in the veins), and suggested geologic signs that might point to the presence of vugs.

The next few days were consumed by the preparation of business plans. Reflecting Land's resolve to contribute the maximum to the war effort[12] and Hoffman's ability and disposition to respond quickly and effectively, they and Polaroid negotiated and signed a contract on October 31. Engineered development of the Palm Wash deposits was underway.

That there could be a reasonable contract was remarkable. The survey of the deposits was more an expedient walk-through than a vigorous analysis. There was no time to assess reserves, to estimate yields, or to forecast production costs. The terms of the contract granted the Hoffmans a generous salary and a liberal allowance for personal expenses. Crystals were to be delivered at cost and provisions were made to give the Hoffmans rights to profits when the operation was liquidated. Polaroid agreed to supply the equipment, assets, and operating capital.

With acceptance of Land's assignment, the Hoffmans found themselves in a new role—operational, not developmental and advisory. Motivated "by patriotism, not gold,"[13] to accept the challenge, their initial enthusiasm was soon tempered by the realities of launching an enterprise in the face of wartime priority allocation of materials, manpower, and equipment.

Two years earlier Congress had authorized the Reconstruction Finance Corporation (RFC) to acquire strategic and critical materials. One of its branches, the Metals Reserve Corporation, had been established to make loans and otherwise increase production of needed metals and minerals at small mines and processing operations. Although both organizations had vigorous programs underway by late 1942 to acquire quartz crystals and mica, neither could help Calcite Operators because optical calcite had not yet been declared a strategic material . Without the "strategic" classification, the calcite mining operation had no direct priority rating. Whatever priorities it could claim were probably an ineffectual trickle-down from the priority carried by the contract the Navy award Polaroid for development of the ORS.

Before extensive mining could begin, there were several tasks to be accomplished despite problems brought on by wartime shortages, rationing, and lack of priorities.

First, they must build a mining camp. The

location was too remote and access to it too difficult for miners to commute to the site, so a camp at the deposits had to be built. Second, an ample supply of water was needed. Neither men nor drills could function long without it and there was none available on site. Next, they needed suitable vehicles. At that time, the trip to the mine was a rugged, 10-mile drive along the bed of Palm Wash. Four-wheel drive vehicle in which to get men and materials to the work site were mandatory. Finally, the company needed to build a road. Driving along the bed of the creek was neither efficient nor practical, and rains made that route impassible.

Learning that an Army installation near Salt Lake City had granted temporary furloughs so 5,000 enlistees could work in local mines, Hoffman believed that help for his calcite mine was close at hand. Huge numbers of soldiers and vehicles were being amassed east of Indio for field exercises at the nearby Desert Training Center (DTC). On behalf of the optical ring sight, he and Polaroid appealed to General George Patton for help to drill wells and build a road.[14] Patton's reply has been lost, but Calcite Operators quickly understood there would be no relief from the general or the DTC.[15]

Fortunately for the ORS program, the U.S. Marine Corps took the situation in hand and provided an unorthodox solution—one without priorities and without paperwork. From late 1940 Polaroid had worked successfully on a number of optical devices for the Navy and gained its respect "as a promising scientific problem solver."[16] Its Vectograph system produced the illusion of three dimensions or "depth" in photographs. When applied to aerial reconnaissance photographs, the effect greatly enhanced object recognition. The first to use it in combat were the Marines while preparing for the battle for Guadalcanal in August, 1942. They concluded that the system greatly improved pre-invasion intelligence thereby increasing the success of the initial landings. Polaroid had made an all-out effort to supply the systems on short notice. When a representative for Polaroid appealed to the Commandant of the Fifth Naval District at San Diego for help at Palm Wash, he was warmly assured of assistance.[17] Three trucks with drivers from the 12th Marines at Camp Dunlap in Niland were assigned to the mining camp for the duration.

Now, work to establish the mine moved ahead rapidly. One of the trucks, fitted out as a water carrier, made daily trips into camp with the precious fluid—water for drinking, cooking, and drilling. (Later, the California Department of Highways loaned a 500-gallon tank and the War Production Board provided a 2,000-gallon tank.)

With water, there could be men, and with men there would be mining. Work was begun promptly on building a camp. A site was selected at a natural amphitheater near the vehicle exit from the Wash and below the workings high in the foothills above. Tents and one or two structures were placed in a circle around the perimeter of the bottom of the bowl. Improvements and additions were made regularly until the camp boasted a cook shack with a large mess hall, a drill repair shop, a dynamite storage shed, an office, bunk houses for the bosses and prospectors, and canvas shelters for 35-40 workers.

Robert Hoffman's field assessment the amount and access to crystal float at Palm Wash gave the brother team reason for optimism. Their easy access to surface float, in fact, sustained early "production." If they were to provide 1,000 pounds per month, however, as they had assured Polaroid, they would soon have to put picks into the ground. What was not so obvious was "which spot" to begin digging.

The recovery of crystals was unlike other mining operations. (Hoffman likened it to "gem extraction."[18]) There was no well-defined body of ore to work, no seam or vein with proven values to chase, no background of experience or lore to predict where the "values" might lurk. The crystals of true optical calcite were randomly dispersed throughout the calcite deposits.

The Palm Wash or Hilton deposits extended over an area estimated at from one to two square miles. Within this area was a complicated network of faults, fractures, and joints where calcite had been deposited as veins. Large crystals ("block calcite") were found in the veins and in the linings of cavities or pockets created by breccia blocks or by the junction of two joints.[19] This material was milky and otherwise unusable for optical purposes. The clear, near-perfect crystals,

when there were any, grew at the centers of the pockets. Cavities were discontinuously distributed along the joints and ranged in size from inches to feet, one crystal measuring two feet wide and 30 to 40 feet long.

Calcite Operators produced crystals intermittently during the first several months. If a pocket were productive, it was emptied of usable material and the crew moved on. Frequently, the cavity yielded no optical material and this led to much barren development and a continuing need for prospecting. By June, 1943, Calcite Operators filed proof of development on a mill site and twenty-four claims.

The Hoffmans continued the technique used by all their predecessors at Palm Wash for prospecting optical calcite. The source was explored carefully with a hoe. If the probing indicated the presence of usable calcite and a pocket, the site was marked for future excavation. The recovery of optical calcite, as with the other strategic crystals, was a hand mining operation. At Palm Wash all crystal recovery was accomplished from open cuts. Wherever a prospect had been staked, the miners and muckers opened a trench in the country rock along the side of the cavity or vug. Breaking through the exposed face of the crystalline mass, they would discard the milky block crystals that lined the vug. With the center exposed, they would carefully remove the clear plates which were usually growing perpendicular to the walls. Mining was extended laterally along the vein until the vug pinched out. It was continued vertically as long as the vug was productive or until exhaust fumes from the gasoline-driven drill would not clear the trench—usually at about thirty feet.

The country rock enclosing the veins had weathered and oxidized to a depth of about five feet. This material could be removed with a pick and shovel, but below the oxidation, the rock was too hard to be readily broken up with a pick. For the hard material, crews used drill rods and Barco gasoline-driven hammers.

In early February, 1943, the California Department of Highways began grading a road from Truckhaven to the camp using a grant of $20,000 from the federal government.[20] By mid-March they had completed the road and extended it above the camp to the main lower workings. This was a boon to the men and a boost to production. Not only could they be driven up to the mining site, but the 80-pound hammers, the steels, the batteries, and the gasoline no longer went up and down on the backs of the men. The biggest benefit of the road was the ability to haul an air compressor to the workings and replace some of the Barcos with air hammers. By eliminating toxic fumes, some trenches were deepened another twenty feet or more. In general, the men working with the compressed-air drills were more productive than those using gasoline Barcos.

Extending the road from the camp to the workings yielded other benefits. It enabled an improvement in quality control and increased the percentage of "acceptable" crystals shipped to Polaroid. Previously, the miner sorted crystals as he removed them from the vug, discarding anything he judged not shippable. The "good" crystals were set aside and backpacked to camp at the end of the day. Understandably, the distinction between "good" and "bad" could be influenced by the weight of the load. As the miner was not trained in inspection techniques nor quality criteria nor equipped with inspection tools, his sorting was, at best crude and wasteful.

After the road was extended, the miner set aside all crystals removed from the vug. These were collected by one of the Marine drivers and trucked down to camp. At the camp, one or more of the men, usually one of the prospectors, was assigned to sort crystals and prepare them for shipment. Crystals that were entirely milky were discarded. Those with milkiness around the edges were cobbed. A sharpened putty knife was placed on the crystal at a spot between the milk and the clear and given a light tap. If the knife was placed skillfully, the crystal cleaved, cleaning separating the milky portion from the clear. All potentially useful crystals were then immersed for a few minutes in dilute hydrochloric acid, washed and dried. The acid removed any light surface film and facilitated examining the interior of the crystal. When a crystal showed a portion about 1-1/2" square that was clear, near-colorless, and free of bubbles, cracks and twinning, it was passed for shipment. Doubtful crystals were examined further under polarized or near-ultra

violet light which better revealed twinning and other small internal defects.[21]

Crystals that were accepted at the camp were wrapped in newspaper and carefully packed in wooden boxes. The boxes were trucked to an airport north of Indio where U.S. Air Force aircraft whisked them to Polaroid. At Polaroid the crystals were re-inspected and payment or credit was made only for those accepted for sight production.

Weathering rendered the country rock friable to depths of two to five feet. The weathered material could be excavated readily with a pick and shovel. Below the weathered zone, the rock was very hard and exposing the vug progressed slowly even with the powered drills and pavements breakers. The use of explosives was scrupulously avoided at the start of operations because the detonation usually fractured and destroyed calcite crystals.[22] The Hoffmans experimented with the use of powder and established the feasibility of using dynamite for "shooting along benches"[23] and production was significantly increased as a result.

As Robert Hoffman predicted, finding adequate numbers and skilled workers proved difficult during the war. The military had successfully pressured federal agencies into closing the gold mines in 1941.[24] However, this achieved little toward driving men into the mines for critical metals like copper[25] and accomplished nothing toward establishing a pool of experienced mines for Palm Wash. Likewise, there was no lack of civilian employment opportunities around Indio, especially in light of the need for service and supply created by the enormous growth of the DTC. Military construction opportunities abounded throughout the region and generally paid better than mining.[26] To work at the calcite mine meant being confined in an isolated camp for two weeks at a stretch. Not many agreed to suffer this isolation for long. Younger men who were willing to relocate or be away from their families for long periods preferred the higher wages and better working conditions of the coastal aircraft factories and shipyards.

Gradually, however, Calcite Operators found workers, half who were Native Americans and half Anglos. A few of the latter were locals from the Indio area. Several were college students Arnold Hoffman personally recruited from the California Institute of Technology, the University of Southern California, and several other colleges in southern California. Irwin Hoffman labeled the rest as "draft dodgers, criminals, and and anyone that was trying to get away from the law..."[27] Contrary to historian Gerald D. Nash's insistence that miners were not exempt from military service,[28] several at the mine obtained deferments throughout the life of the project.

A primary purpose of the U.S. Employment Service was to funnel workers into war industries. It may have been effective for the well-paid glamour jobs in aircraft manufacture, but it was no help to Calcite Operators. Arnold Hoffman complained "the type [of worker] obtained was so poor that we feared they [sic] would cause our own force to deteriorate. All told we obtained only one fair worker from over twenty men tried."[29]

The Hoffman's predecessor at the calcite mine was an artist and local *bon vivant* named John Hilton. Hilton arrived in the desert in the early1930s, during the Great Depression. He made many contacts, especially with Cahuillans, at his art and rock shop. He persuaded a number of his Indian friends to sign on at the Hoffman's mine.

The Indians were good workers albeit a trifle independent regarding work schedules and length of employment. Outstanding among them were Salvador Lopez, a shaman, and Dan Segundo. Segundo was a 300-pound giant, so powerful he could hold an 80-pound Barco in one hand and drill horizontal holes.[30]

No one bothered Segundo and his presence served to curb Anglo prejudice. For a time, Cecil, a *macho* Marine, did pester the Native Americans. On his return from Guadalcanal, for rehabilitation, Cecil brought a pet monkey. Late one night Cecil tossed the monkey into the tent of two Cahuillan men who were sleeping. Within seconds the men shot out of the tent angry and frightened and disappeared into the night. They never returned to the mine, to the dismay of Calcite Operators. However, Cecil got what he deserved. A few nights later, he slid into his sleeping bag only to discover he was sharing it with a

rattler. Thereafter Cecil spread his bedroll in the metal bed of his GI truck, yet continued to act ugly to the Indians. One evening when his attention was diverted, someone wired a battery and magneto from a Barco drill to the bed of his truck. When Cecil reached for the truck and his bedroll, he arced like a sparkplug. That retaliation finally readjusted his attitude.

The work "week" was 11 days on, then three days off. The work day was generally from sunup to sundown. The men were served a hearty breakfast and left for the workings carrying a large sack lunch which they ate in the field. The evening meal was built around meat and potatoes. For a time, food rationing made it difficult to feed the men adequately but, after a couple of months, a Ration Board granted them institutional status, and food was plentiful.

Help from Camp Dunlap went well beyond supplying trucks and drivers. The Camp had a large meat locker which they shared with Calcite Operators, allowing them to store sides of beef. Relations between the two facilities were so cordial that the mining camp was named Camp Wilson in honor of Colonel Wilson, commanding officer of the 12th Marines. The Colonel and his staff were frequent visitors at the mine and on two occasions, one at the mine and one at Camp Dunlap, Salvador Lopez demonstrated his power as a shaman which enabled him to walk barefooted with impunity on live coals.[32]

When the men tired of camp food, the Marines would haul them to Truckhaven. Near the junction of the Palm Wash road and the Indio-Westmoreland Highway was a filling station and a small restaurant, called "Truckhaven." Here the men showered, ate, drank beer, played the juke box, and flirted with the waitresses. Later, the Hoffmans brought in a gasoline-driven motor-generator set and wired the cookshack and mess hall and the office for lights and fans. They borrowed a projector and once a week the men watched movies.

At about the time Berman persuaded John Hilton to mine at Palm Wash for Polaroid, he approached another self-styled mine operator named Al Hansen of Clyde Park, Montana. Hansen had located a promising vug on a farm owned by celebrity figure skaters, Bill and Betty Wade in the Big Sky state. After lengthy negotiations Calcite Operators leased from Wade the right to mine his calcite for three years. In turn, Calcite Operators contracted with Hansen to do the mining. Calcite Operators (Polaroid) paid Wade a royalty of fifty cents on each pound of crystals Polaroid accepted and paid Hansen fifty cents for each pound of "acceptable" crystals he produced. They also paid Hansen's operating expenses as well.

The Hansen vug proved a rare find, seventy feet long, thirty feet wide and three feet thick. It produced 9,600 pound of crystals, Polaroid accepting 3,270 pounds. The vug was worked by the same open-cut methods used at Palm Wash. Until the vug was exhausted, Hansen employed seven men. Cost to Polaroid for the accepted crystals was an astonishing $2.08 per pound.

During frequent trips to Montana, the Hoffmans gave Hansen advice on mining, advanced money for his expenses, and coached him on grading crystals. They also spent time assessing prominent calcite veins that abounded around Clyde Park and Brackett Creek which lie about fifty miles north of Yellowstone Park. The veins of calcite were wider, appeared to extend deeper, and, in some cases, ran for miles. They concluded the area had more potential than Palm Wash. Instead of mining by open cuts where a surface outcrop suggested a vug, as at Palm Wash and as Hansen was doing, they proposed sinking a shaft at a promising spot and removing by *underground* mining all the subsurface veins and vugs encountered in the chase. They, with Berman, began promoting this approach to Polaroid in January, 1943, and by May were given approval to proceed.

Even though the Hoffmans assured Polaroid they would continue optimal production at Palm Wash, they gradually curtailed operations there. Between July and October they abandoned the California operation. They sold off what equipment they could, leaving only the buildings and the claims. They fired all the workers, with the exception of Blazovic, their superintendent and Jack Frost and Bob Dye, their best prospectors. After a summer in Clyde Park in what Frost described as "leisurely prospecting and excellent fishing," he and Dye returned to Palm Wash

where they worked the Polaroid claims with considerable success for the duration of the ORS program.

For the next five months the Hoffmans produced successful mining operations at Clyde Park. First, they prospected and obtained leases on several farms on the same royalty terms agreed to with the Wades. There were enough differences among the deposits that some were worked by the usual underground methods of drifting and stoping and some by open cuts.[33] They gradually hired enough miners and equipment to operate three shifts, but shipments of crystals to Cambridge were small.

Perhaps the Hoffmans' greatest contribution in Montana was the Crystal Shop. Previously, the mined material was sorted, graded, and boxed for shipment at the mine head. Now, all mined material was trucked to Clyde Park for grading and sorting. Crystals were dipped in acid and examined for internal defects under blue light. However, here specially trained women workers sitting at specially constructed work stations split (cobbed) unusable material away from the clear portions of the crystals. This procedural change increased the proportion of acceptable crystals among the material shipped to Cambridge. In turn, the change saved scarce wartime shipping and improved the efficiency of Polaroid's material handling.

The shop was located in a former telephone building in the center of Clyde Park and was staffed by a supervisor, two helpers, and four inspectors. Professor Berman personally trained the inspectors. He was a short, plump fellow with black, curly hair and a warm, out-going personality which allowed him to interact as effectively in the farming community as in the university. In about a week under Berman's tutelage, the women workers became proficient in inspecting, grading, and trimming the crystals brought from the mine. Adapting the popular wartime song, "Pistol Packin' Mamma," the miners dubbed the female inspectors, the "Crystal Crackin' Mammas."[34]

The Hoffmans soon began to pay a price for the changes they were introducing. By working only the vug and ignoring adjacent vein material, Hansen achieved a close ratio between the weight of crystals removed to the weight shipped. Even though Polaroid delayed acceptance of crystals and payments, Wade was satisfied with the pay. When the Hoffmans began mining out all the vein, Wade saw truckloads of material going into the Crystal Shop but, because of even greater delays at Cambridge in accepting crystals, yet with few or nor royalties, Wade soon became convinced that Calcite Operators was highgrading his crystals and that Polaroid was cheating him.

Berman and the Hoffmans had a solution for that, too—one which would improve material flow and allay the fears of the ranchers. Calcite accepted at the Crystal Shop would go next to a cutting shop. There it would be oriented and sliced into slabs. Thereafter, only slabs would be shipped to Cambridge. Acceptance of crystals for payment would be made locally and promptly. Polaroid would receive only material acceptable for further processing into wafers.

Polaroid's middle management approved this concept and the three men vigorously set about implementing it. A new company was formed, Crystal Cutters, Inc.[35] Machinery and equipment and tools were shipped from Cambridge and set up in Livingston, Montana. There is no record of how the cutting operation was financed, how Berman and the Hoffmans were compensated for work done in the cutting room, and how slabbing costs at Livingston compared with comparable costs at Cambridge. Berman was convinced he would outproduce Polaroid. However, Land was not about to relinquish control of his product or his processing. Suddenly and without explanation word came from Cambridge in mid-August, 1943, that crystal processing would be performed at the Polaroid plants only.

The failure of Crystal Cutters left the three men frustrated and bitter; Berman so much so that he subsequently wrote the Navy defending the Hoffmans and declining to make further input on Calcite except directly to the Navy.[36] But, there was much more trouble on its way. There was a growing determination at Polaroid to get out of the mining business. In the face of an increasing need for crystals, Hoffmans' production was very low and the Montana "potatoes" were harder to process. The cost of crystals was hovering around $20 per pound, not the $10 anticipated, and

Polaroid's investment was approaching a quarter of a million dollars. Polaroid had argued from the beginning that the supply of calcite crystals should be a government function,[37] and they announced in September to the military and to the War Production Board that continuation of their contract with Calcite Operators beyond its expiration in November would depend on crystal production results during the ensuing two months.[38]

Demand for the ORS seemed to be growing. The military had been slow to articulate its need for the sight. In July, 1943, Polaroid received firm orders for only 16,000 units, with a potential for another 174,000. There was increasing talk—but no firm action—about the potential requirements.

In the meantime, relations between the Hoffmans and the lessors were worsening. Wade in particular was determined to break his contract with Calcite Operators, and filed suit. The Hoffmans were hot-headed and their abrasive manner exacerbated the situation.[39] In October the pot boiled over. First Polaroid notified Calcite Operators that it would not renew their contract. Calcite Operators in turn gave termination notices to its employees, began to liquidate assets, and prepared to shut down the mine. Bill Wade was elated.

On October 28, the Navy appealed to the War Production Board (WPB) to help Polaroid obtain optical calcite from Mexico, citing a new, firm requirement for about 100,000 sights. The WPB immediately wired the Hoffmans urging them not to interrupt operations and guaranteeing their expenses. Bill Wade was depressed.

On November 8, Wade assembled a group of ranchers, including his wife and Al Hansen, which successfully locked out Robert Hoffman and his first shift from Wade's property. Because Calcite Operator's mining equipment was on the Wade property, this effectively shut down their calcite mining. Hoffman telegraphed a report of the incident to the WPB which immediately wired an appeal to Wade to allow mining to continue in the interest of the war effort. Wade promptly returned his refusal to have any further contractual relationship with the Hoffmans and allow them back on the property.

Representatives of the WPB flew to Clyde Park, and Metals Reserve Company (MRC) engineers examined the operations. The property owners opposed continuing with Calcite Operators. Clearly the Hoffmans' effectiveness in Clyde Park had ended. A compromise was arranged and the Hoffmans agreed to relinquish all rights to leases in the area if Wade agreed to drop his suit for damages.[40] Henceforth, the MRC would be in charge of crystal production at Clyde Park.[41] Polaroid relinquished its calcite crystal production to the federal government.

After a few weeks, the MRC contracted with mining engineer, Leo J. Coady, to produce optical calcite for the Navy. Their arrangement was similar to the one between Polaroid and the Hoffmans. Coady hired and paid the employees and ran the operation; MRC financed it. President Franklin Roosevelt had just declared optical calcite a strategic material so now there were priorities for procurement. The War Production Board formally charged the MRC with the responsibility for running an optical calcite program that would meet the country's needs.[42]

Coady was a sharp contract to the Hoffmans. Where Bob Hoffman, in spite of his reputation with the ranchers, had a friendly, informal relationship with many of his employees, Coady was kindly, but aloof. Coady was always well dressed, and drove a "fancy" car, accompanied everywhere by a red Chow dog.[43] Hoffman was more likely to be seen dressed like one of his miners (he had probably just come up from the bottom of a shaft) and driving one of the old trucks.

Coady continued the operations as Calcite Operators had installed it. He worked open cuts and mined out calcite veins with drifts and stopes; trucked the vein material from the mine to Clyde Park; and sorted, trimmed, and shipped the acceptable crystals at the Crystal Shop. The Crystal Shop became the collection center for calcite crystals offered from sources not mined by MRC and did custom grading for the independent producers. Some of these were the reactionary farmers around Clyde Park who steadfastly refused to allow the government to mine their deposits. Others were part of the growing response to the government's now-active program to stimulate production of optical calcite. Most of the custom work came from deposits in the area, although some came from Colorado and

British Columbia. The independent producers were promptly paid $7.50 for each pound accepted by the Crystal Shop. During the Shop's existence under MRC, the "Crystal Crackin' Mammas" processed 540,000 pounds of crystals.[44]

MRC bought all of Calcite Operators' (Polaroid's) trucks and mining equipment, but Coady soon replaced much of it with safer and more powerful machinery obtained from a war-casualty gold mine at Nye. He rehired Calcite Operators' employees and steadily added more until his crew was three times as large as the Hoffmans'. His production increased but so did his costs.

Accurate numbers are not available to measure the Hoffmans' performance during the six months they were active in Montana. It is probable that they produced only 2,000 pounds of acceptable crystals at a cost of about $30 per pound. This compares poorly with their record at Palm Wash where they produced 6,900 pounds of acceptable crystals at about $15 per pound. Even that performance pales when compared to that of Frost and Dye who, working alone on the same deposits, shipped 3,459 pounds of the "best crystals Polaroid had seen" at cost of only $12 per pound.

The contribution of the Hoffmans in Montana compares favorably with the experience of MRC. Data for the amounts of earth removed by Calcite Operators are not available but we do know that Coady sank 672 feet of shaft, ran 2,578 feet of drifts and crosscuts, and drove 996 feet of raises. His underground stoping totaled 2,073 cubic yards. In addition, he performed 7,538 yards of surface excavation.[45] It is reported that he mined 484,878 pounds of calcite as of August 18, 1944, of which 4,722 pounds (less than 1%) were usable.[46] The distribution of his production between underground and surface mining is not known, but, all told, his yield was only 0.3 pounds per cubic yards of surface excavation compared to 1.12 for the Hoffmans at Palm Wash. At any rate, Coady's costs were over $36 per pound of acceptable crystals.

In August, 1944, the Navy advised MRC that they would not require crystals from Montana after September 1. MRC wired Coady to stop all mining on that date and terminated his contract. The Navy's decision was probably based on three factors: downward revision of the number of sights required, alarm at the cost of Montana crystals; and, success of the joint Polaroid-WPB program to stimulate production of calcite crystals in Mexico. An agent headquartered in Douglas, Arizona, traveled through Chihuahua and Sonora encouraging small farmers to explore for and produce calcite. Prices paid were $4 per pound, fob Douglas, with inspection in the field or at Douglas and $7.50 per pound, fob Cambridge, upon acceptance by Polaroid.

Technical advice on production and grading was furnished out of Douglas and Chihuahua City. Recovery of crystals was almost exclusively by hand mining in open cuts. Of the 9,771 pounds purchased in the field, 52 percent were accepted at Cambridge. Another 5,807 pounds were sold directly to and accepted by Polaroid thus making a total of 10,878 pounds of usable crystals supplied from Mexico in one year.[47] A further advantage to Mexico as a source was that the majority of the usable crystals were of the basal plate type. Except for Al Hansen's vug, the Mexican program was more productive than either the California or the Montana efforts and was by far the least expensive.

The wartime program for production and procurement of calcite crystals—part civilian, part government—can be compared best with the program for quartz crystals. The two materials are similar in that they are both abundant in the earth's crust but large single crystals of them are scarce and lend themselves best to hand mining. Quartz crystals were adopted by the military in 1939 as the preferred means for controlling frequency in electronic communication devices. In 1941 the shortage of crystal was recognized and acted upon by inaugurating an intensive program for acquiring them.

The effectiveness of the optical calcite program may best be gauged by comparing it with the government's wartime program for quartz crystals. In both cases the supply never met the demand and there was a broad, expensive effort to develop domestic sources which fell short of the response from foreign sources. From 1932 to 1940, the U.S. imported a total of 310,179 pounds

of uncut quartz crystals. In 1941, the first year of the quartz program, this number jumped to more than two million pounds. From 1941 to 1945, the total imports were 11,800,000 pounds, almost a forty-fold increase over the prewar period. Prices for imported quartz more than doubled in an attempt to stimulate production. Price for independently produced or imported calcite remained steady at $7.50. There were two major domestic attempts to produce quartz crystals: one in California[48] and one in Arkansas.[49] Yields of crystals suitable for electronic use were 1.4 pounds per cubic yard of material excavated at one and 0.1 pound per cubic yard for the other: one comparable to calcite, the other significantly worse. Yields of electronic grade crystals was 2.5 to 5 percent of all crystals recovered. Keeping in mind that quartz crystal was a critical material after 1941, and that it carried the highest priority of any of the strategic minerals, the calcite program, in spite of some bumbling and stumbling, compared favorably.

Here the similarity between the two crystals ends. The need for quartz crystals, while small after the war, has remained relatively strong as major new electronic applications, such as color television, watches, and microprocessors have evolved. The demand for optical calcite dropped back to prewar levels where it remained until the advent of lasers, fiber optics, and fiber communications.[50] Processes for growing synthetic quartz crystals were successfully developed after the war and have been commercially successful for many years. Synthetic optical calcite has not been successful, although recent reports show the Russians are making use of calcite crystals.[51]

The optical ring sight has fared even less well than calcite crystals. Although it was reported that "several hundred [of more than 30,000 manufactured] were delivered to the services and were immediately well accepted,"[52] the sight never earned a place as a primary aiming device. Regardless, the wartime calcite crystal program was a gallant effort, for the most part, which largely succeeded.

Lew Orrell is a retired professor of metallurgy with a penchant for the history of metals and mining.

MINING CALCITE CRYSTALS FOR WORLD WAR II

Illustrations for Palm Wash, CA Phase

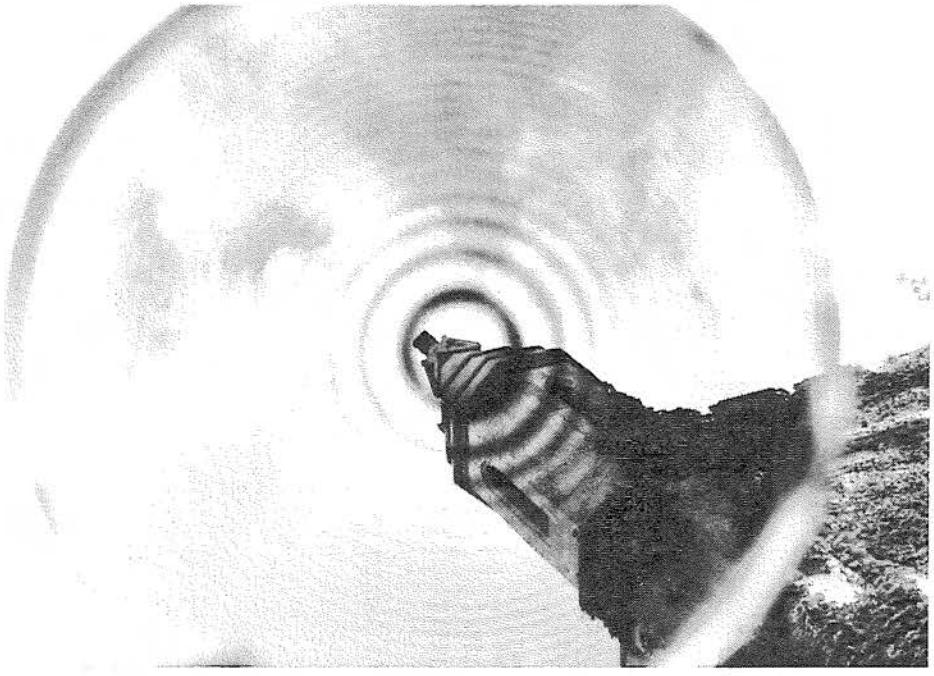

Fig. 1 *ORS concentric-rings sighting pattern overlaying "target."*

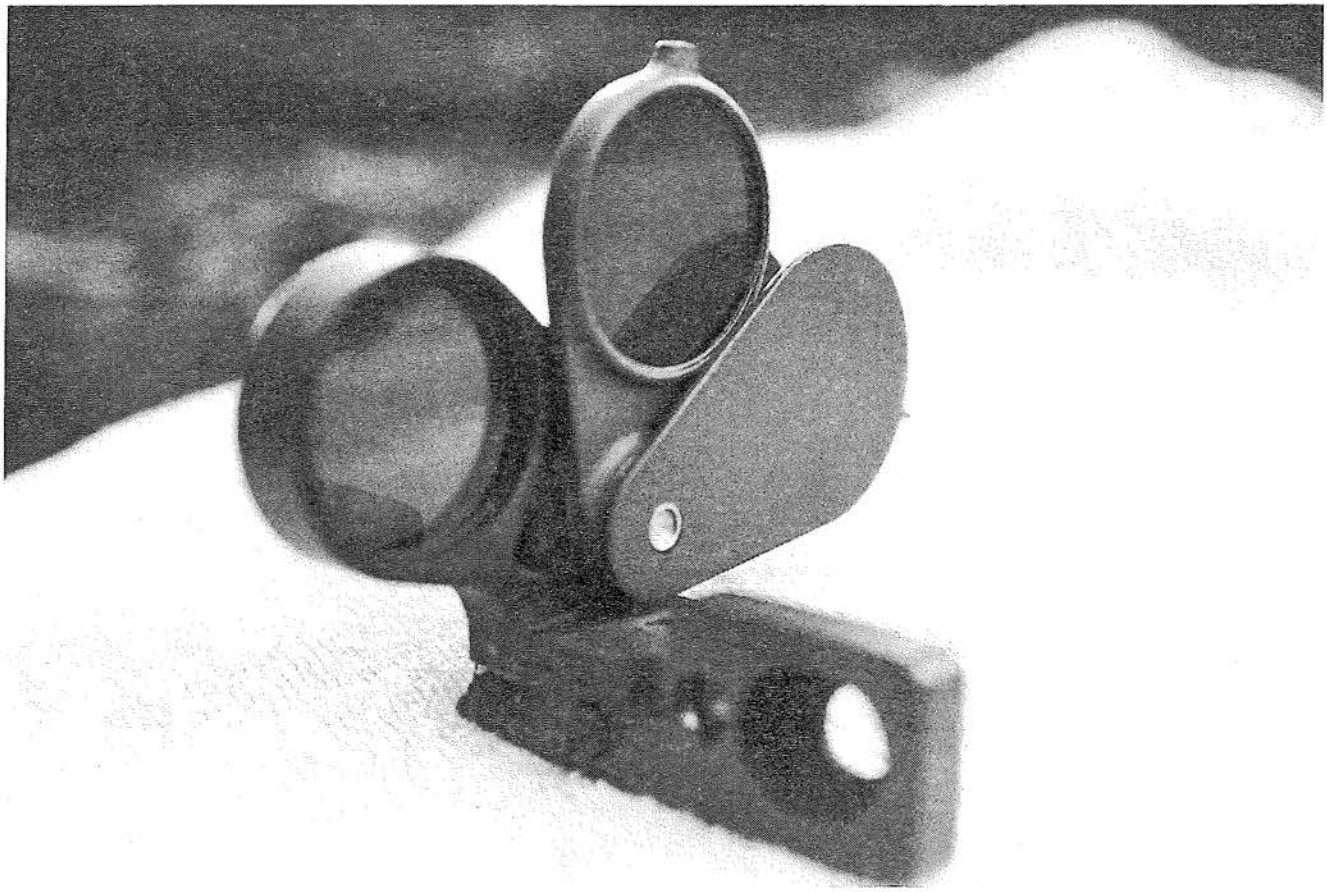

Fig. 2 Optical Ring Sight. Protective covers at right. Vertical element is a red filter which converts colored rings to black and white and sharpens them.

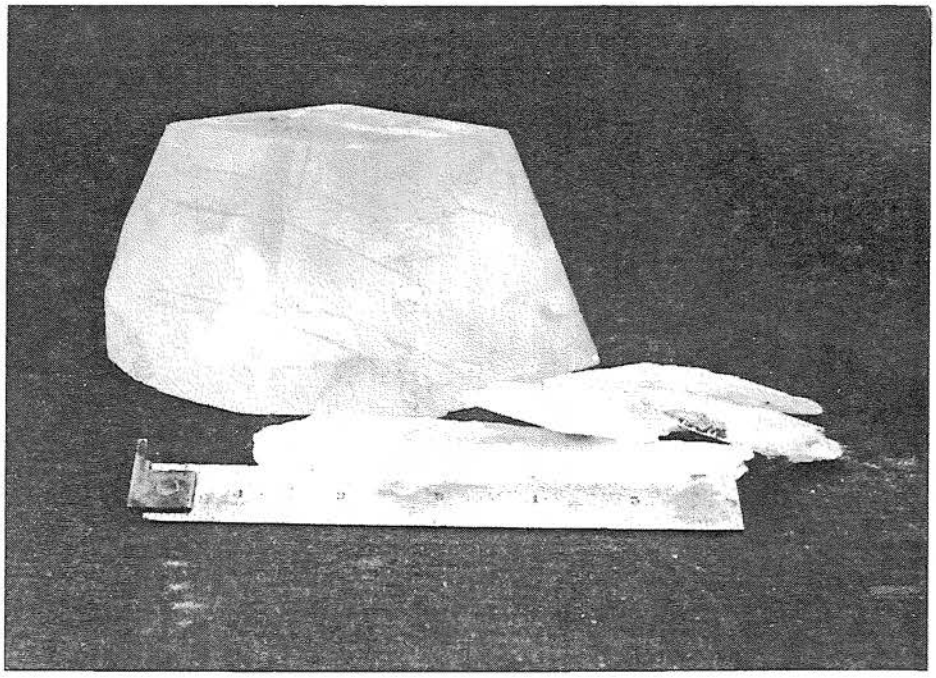

Fig. 3 Calcite crystals. Note cleavage cracks; basal plates on right are too thin for most applications other than the ORS.

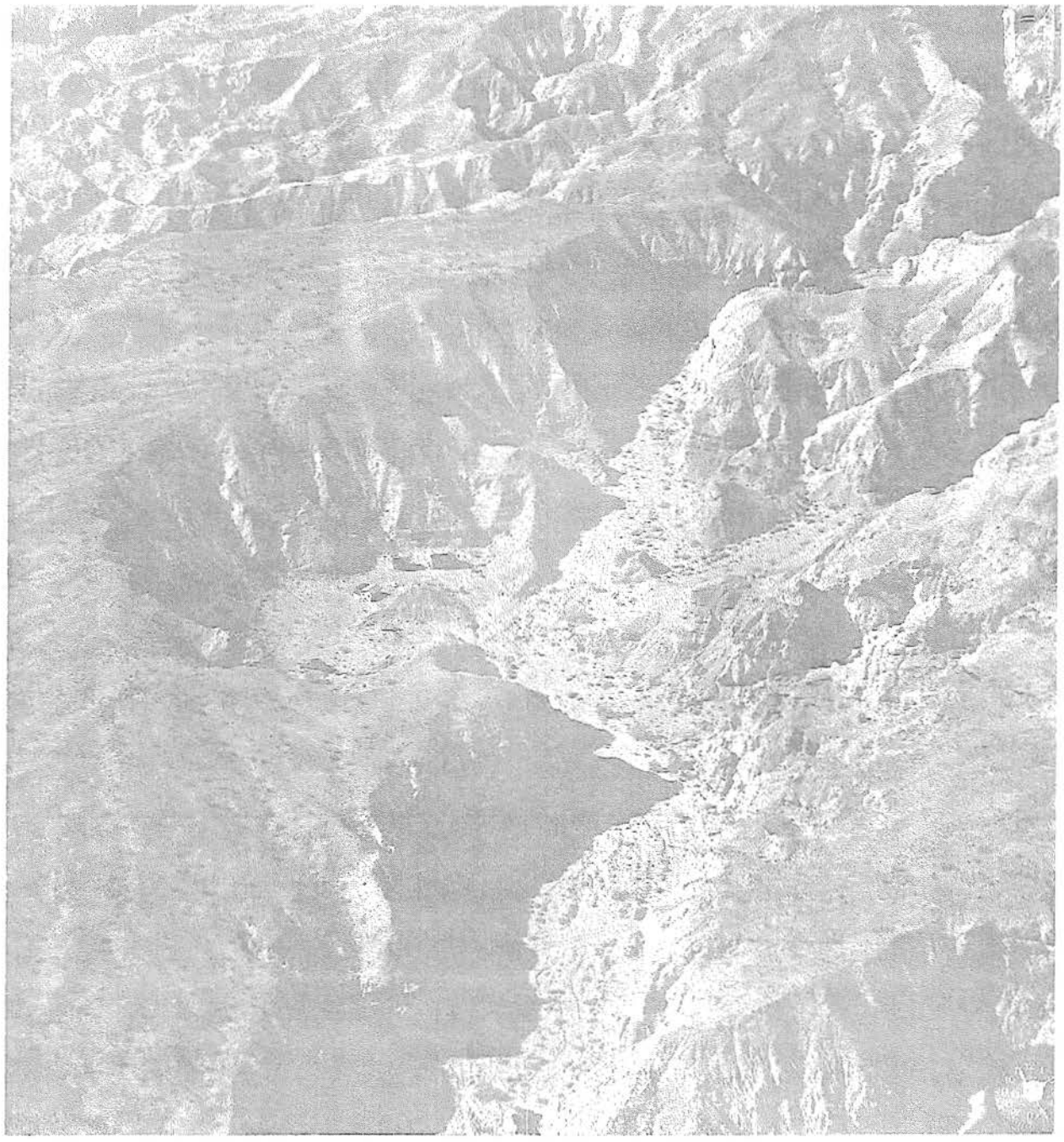

Fig. 4 *Natural bowl in which Camp Wildson was erected. First three of 20 buildings can be seen; Palm Wash runs at edge of bowl from top to bottom of photo. Note height of mesa and ruggedness of terrain.*

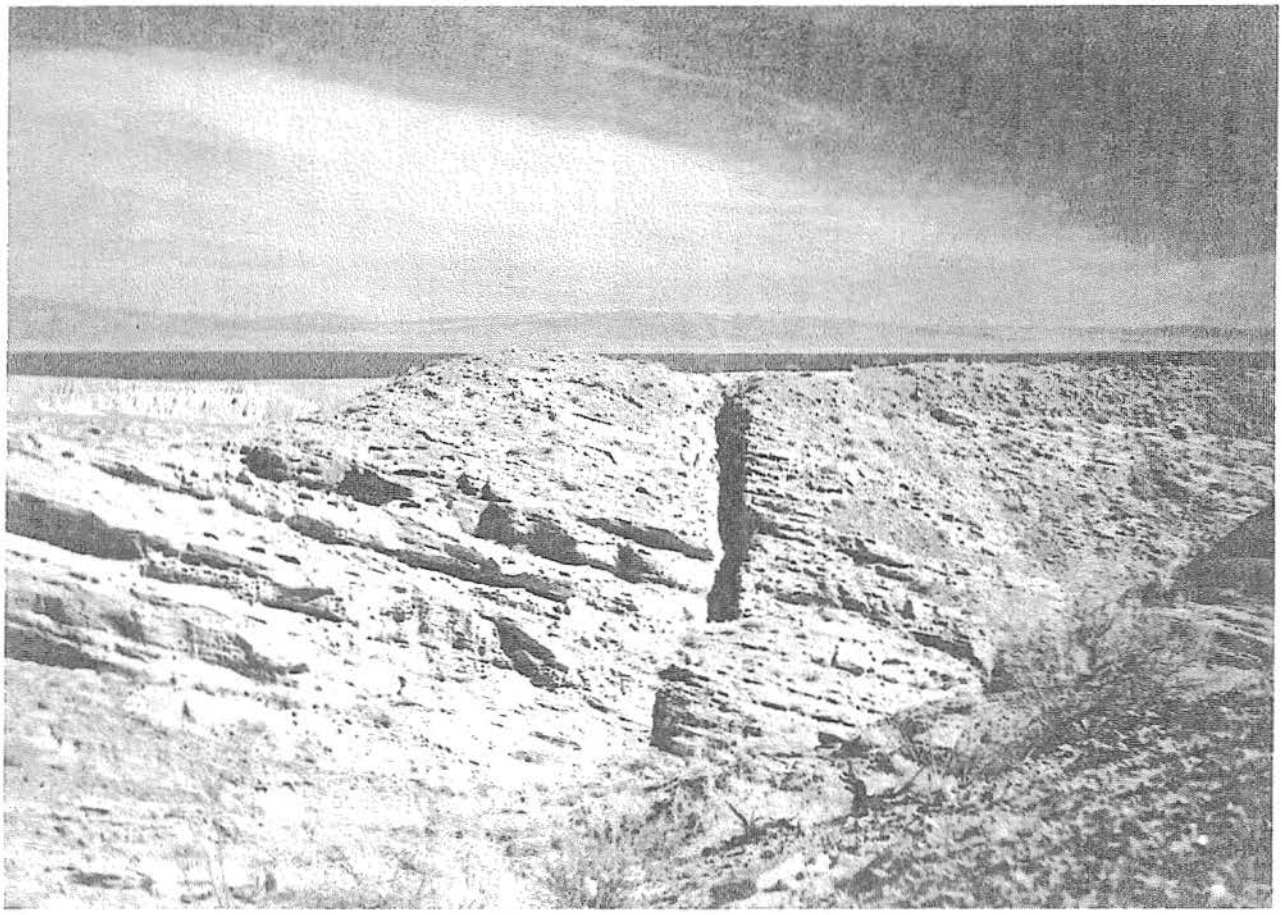

Fig. 5 *A typical open cut at Palm Wash. Note uplift. Salton Sea and Chocolate Mountains are in background. Courtesy Phil Blazovic.*

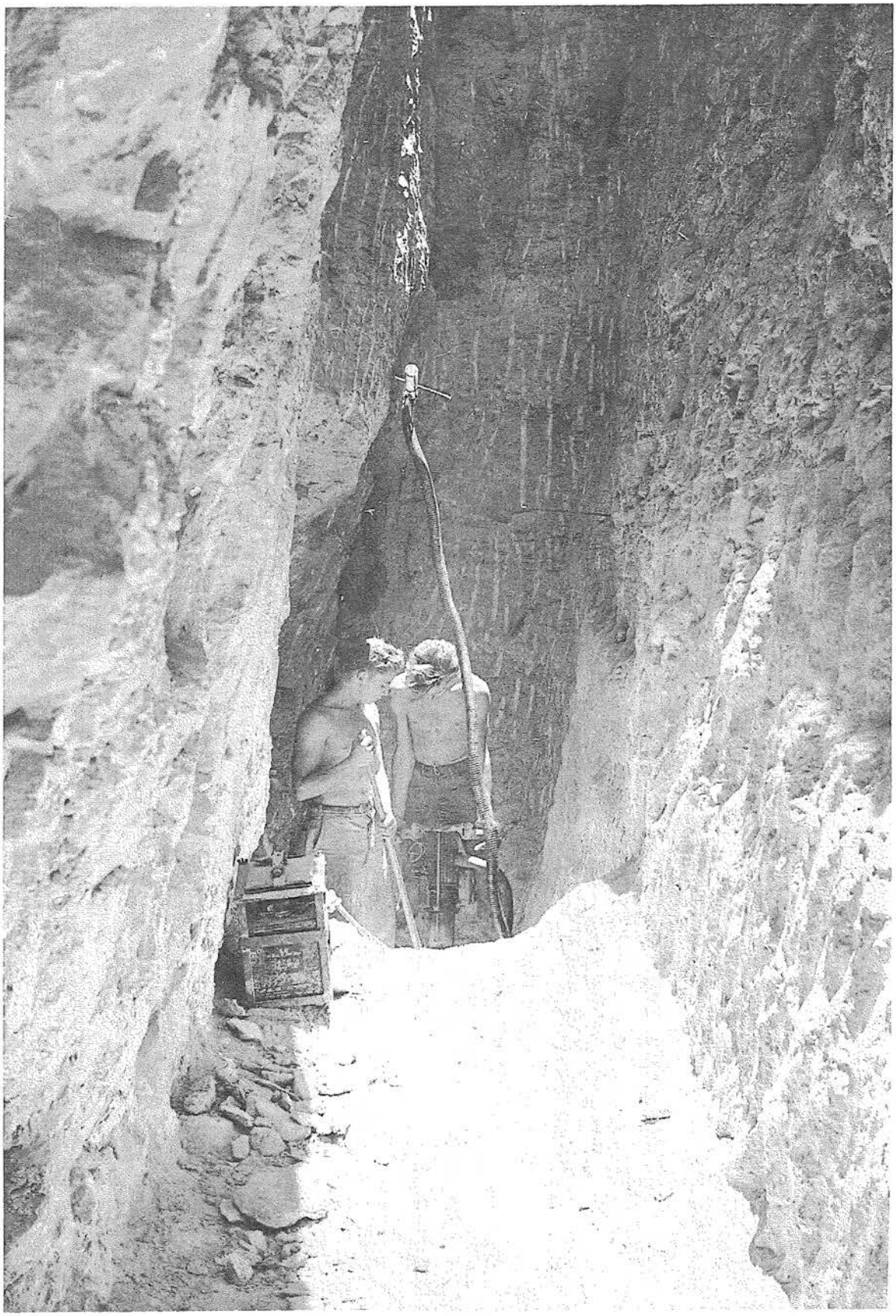

Fig. 6 Young miners operate Barco drill in deep cut at Palm Wash. Courtesy Phil Blazovic

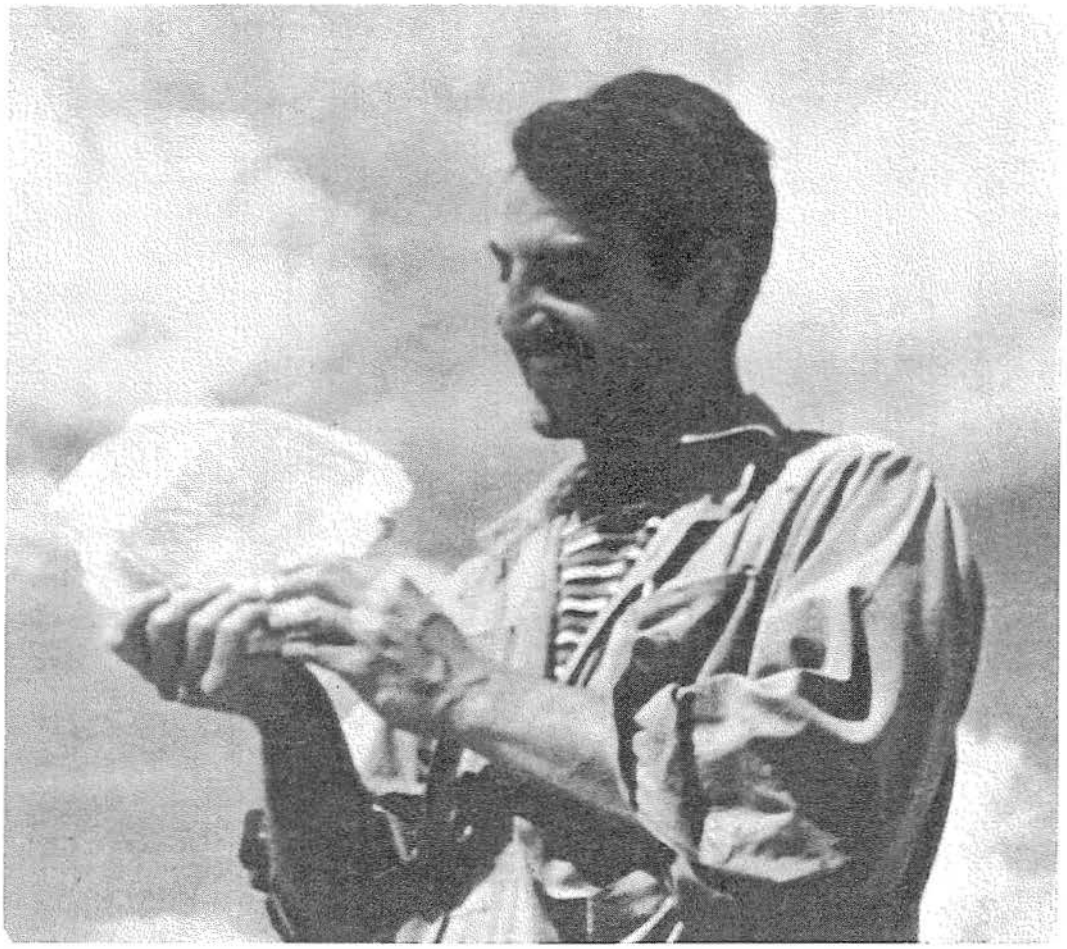

Fig. 7 *Arnold Hoffman admiring a large basal plate crystal at Palm Wash. Coutesy Phil Blazovic.*

Fig. 8 Jack Frost packing crystals for shipment at Palm Wash. Inspection table and acid wash equipment in background. Courtesy Phil Blazovic.

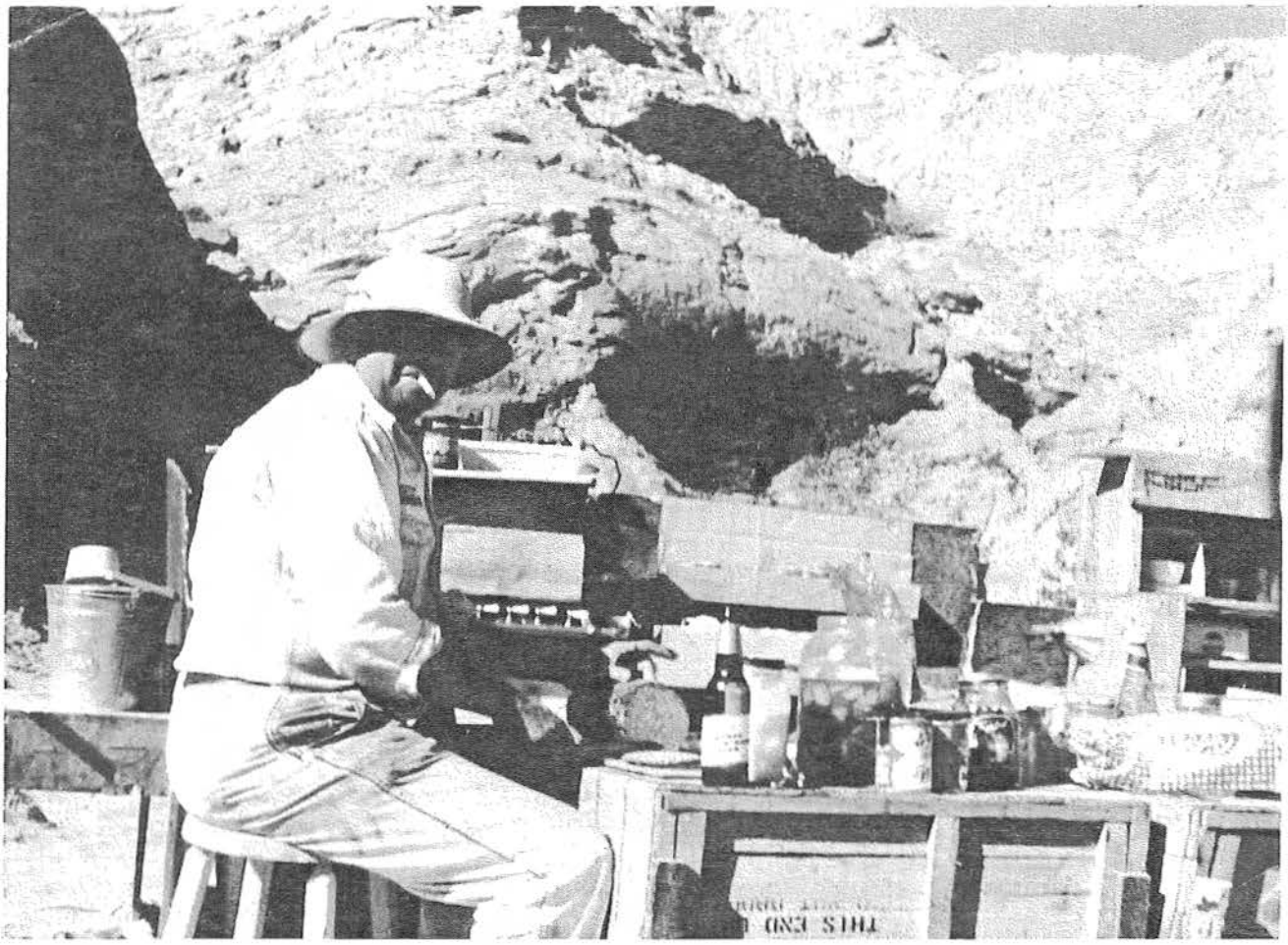

Fig. 9 *"Cookie" prepares lunch at Palm Wash. Note gas stove. Courtesy Phil Blazovic.*

Fig. 10 *Arnold Hoffman and Paul McCulloch supervise construction of building at Palm Wash mining camp. Note Marine helping carpenter. Courtesy McCulloch.*

Fig. 11 Sailor test firing 20mm AA gun fitted with ORS. Courtesy Polaroid Archives.

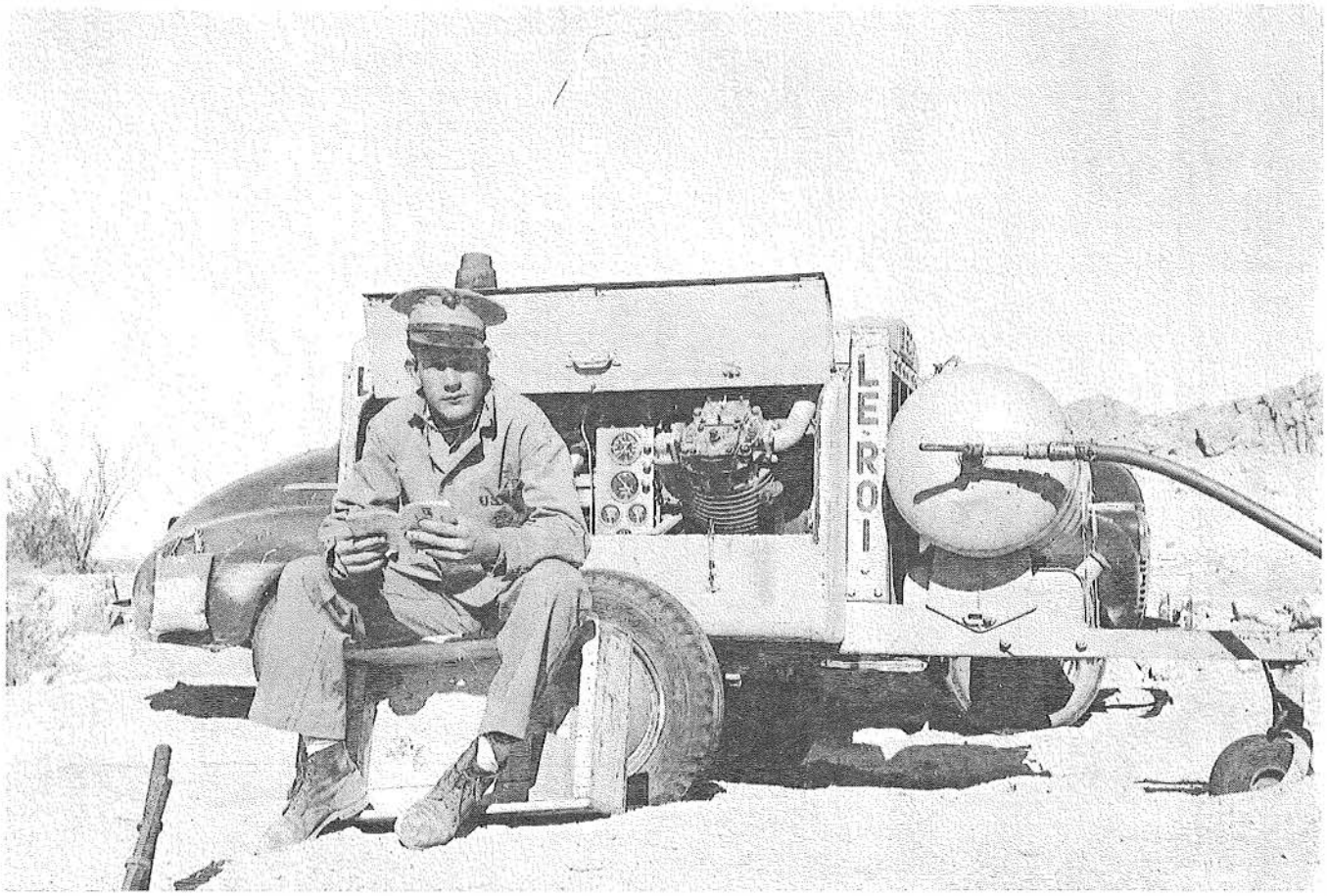

Fig. 12 *Cecil the Marine studying the operating manual for the air compressor at the upper workings at Palm Wash. Courtesy Phil Blazovic.*

MINING CALCITE CRYSTALS FOR WWII
Illustrations for Clyde Park

Fig. 13 *Al Hansen - discovered and worked the Hansen vug at Clyde Park, MT.*

Fig. 14 *Crystal Shop. Photo illustrates "shrinkage" as crystals move through inspection from left to right in photo.*

Fig. 15 *Crystal Shop. Final inspection and cobbing station.*

Fig. 16 Wade Shaft No. 2. Note bucket dump. This undoubtedly fractured otherwise usable crystals.

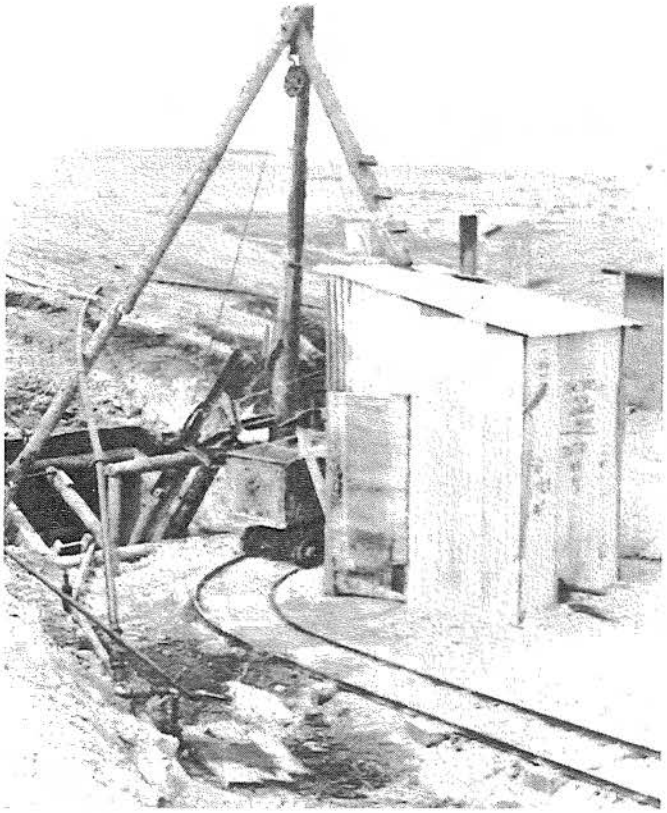

Fig. 17 Killorn Shaft No. 6. Note log A-frame for headframe.

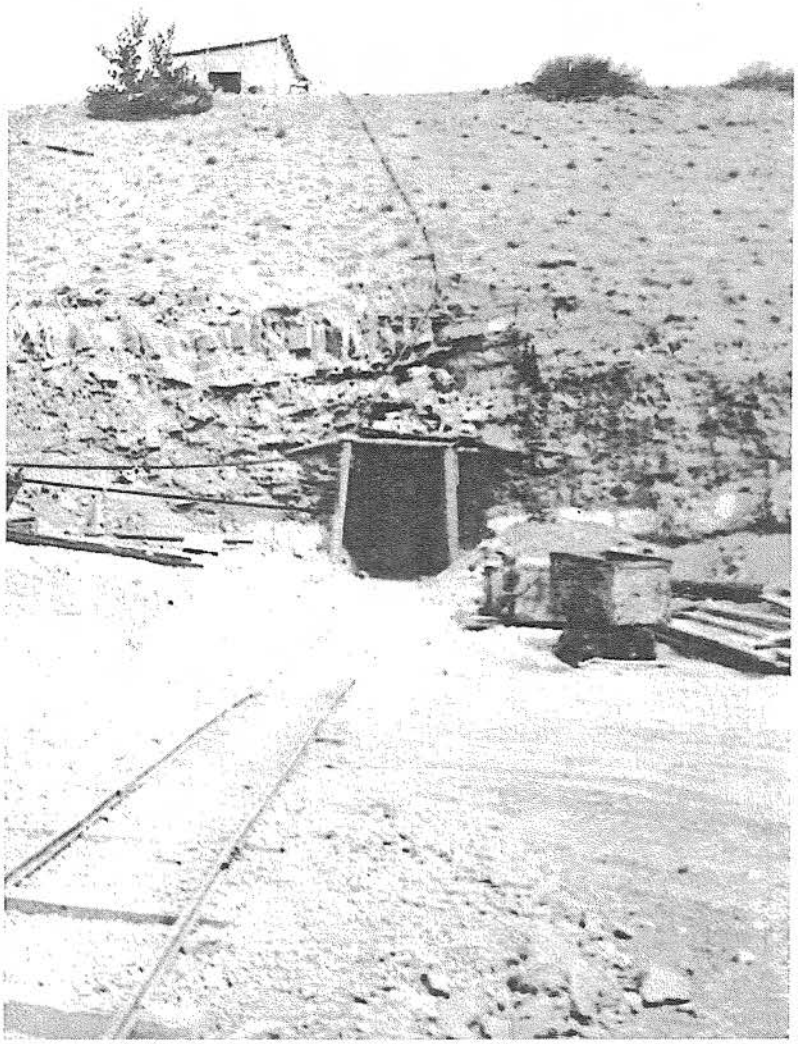

Fig. 18 *Adit to calcite vein at Clyde Park.*

ENDNOTES

[1]For more details of the origin and conduct of the Optical Ring Sight program see F. L. Orrell and Ross Whistler, "A Sight so Good it Almost Succeeded," *Journal of the Council on America's Military Past* xv,4 (January 1989): 3-14.

[2]Robert Paschall, "Calcite: The Multiuse Mineral," *California Geology* (November/December 1994): 163.

[3]Lauren A. Wright, "Calcite," *Mineral Commodities of California,* California Division of Mines, Bulletin 176 (December 1957): 99.

[4]Dr. Bruce H. Billings (interview, November 1985) as a physicist at Polaroid made frequent trips to the Bureau to acquire crystals for early ORS development until Polaroid had exhausted the Bureau's surplus.

[5]Ironically, an attempt was made in 1940 (Ed Atkinson correspondence (Washington: National Archives Record Group RG179, Records of the War Production Board, WPB 528.2211, Optical Calcite: Supply: Sources) and in 1941 (R. B. McCormick, "Optical Calcite Policies and Procedures of the WPB and Predecessor Agencies," p139, National Archives RG179) to have the government stockpile optical calcite. At the time there were no military devices known which required the material nor could anyone envision a need arising.

The English saw the situation differently and gobbled up in 1941 a large quantity of crystals from New Mexico. They had no military application for them but wished to deny them to the Germans who they feared did. These could have been a significant and helpful reserve for the United States.

[6]Clinton J. T. Young, Polaroid Corporation. Letter to Lieutenant Stanley S. Ballard, U.S. Navy, Bureau of Ordnance, October 15, 1942. Washington: National Archives, File S71-3(9).

[7]Simon D. Strauss, "Wartime Procurement of Graphite and Mica from Madagascar,1941," Mining History Association, 3rd *International Mining History Conference,* June 6, 1994.

[8]G. Richards Gwinn, "Mining Optical Minerals," *Mining Congress Journal* (May 1945): 67-72.

[9]Arnold Hoffman, *Free Gold.* (New York: Associated Book Service, 1958)

[10]The Hoffmans did well by their grubstakers or backers. One of the earliest was Quincy A. Shaw, Jr., a Harvard classmate of Robert Hoffman and grandson of the founder of the fabulously-rich Calumet and Hecla copper mine. (Robert D. Hoffman, "The Rouyn Rush," undated manuscript.) Grandfather Shaw was also a cousin of and companion to Francis Parkman during Parkman's storied retracing of the Oregon Trail. A later backer who also had no regrets was Simon D. Strauss, metal market consultant. (Letter to author, December 9, 1986)

[11]Robert D. Hoffman, "Report of Palm Wash Calcite Deposits." Hoffman Collection, American Heritage Center, University of Wyoming

[12]Peter C. Wensberg, *Land's Polaroid* (Boston: Houghton Mifflin, 1987): 74.

[13]Clinton Young (Interview, October 9, 1989), Polaroid's Project Manager for the ORS, heard Professor Berman so admonish the Hoffmans while using a telephone in Young's office.

[14]Letter, Calcite Operators, Inc., to Commanding General, Desert Training Center, November 6, 1942. Hoffman Collection, American Heritage Collection, University of Wyoming

[15]Ironically, a year later the shoe was on the other foot and it was Patton who was depending on Polaroid to solve a critical problem for him. At Kasserine Pass the Germans mauled Patton's tanks. He attributed his loss to inaccurate gunfire caused by the small aperture of the sight for the Sherman's 3-inch cannon. The Office of Scientific Research and Development assigned the problem to Polaroid. Their solution was a cast plastic lens with a much larger aperture. The first production models of the new sight were flown to Patton within two months of his complaint. Wensberg, *Land's Polaroid,* 72-73.

[16]Wensberg, ibid.. 71.

[17]Paul H. McCulloch (Interview July 8,1985), the former western representative for Polaroid

[18]Robert D. Hoffman, "25th Annual Report." (Cambridge: Harvard University, 1944), 394.

[19]After appraising the site for possible government support in 1944, Durrell reported that "...nearly all usable calcite has occurred at the intersections of joints as a filling in previously prepared cavities." Cordell Durrell, "Report on the Calcite Mines in Northeast San Diego County, California, June 1944, *passim* U.S. Geological Survey Open File Report 77-685

[20]This was probably another of the many contributions made to the project by McCulloch. He was so assiduous in pushing the crystal operation, the executives at Polaroid admiringly referred to him as "McCalcite."

[21]Arnold Hoffman, "Interim Report," June 21, 1943. Hoffman Collection, American Heritage Center, University of Wyoming, Laramie.

[22]Gwinn, "Mining Optical Minerals," 72.

[23]Arnold Hoffman, "Interim Report," June 21, 1943.

[24]There were three different orders in 1941 directed against the gold and silver mines: Presidential Executive Order L-1041, June 21, 1941; Office of Price Management Order P-56, July 29, 1941; War Production Board Limitation Order L-208, October 8, 1941.

[25]Gerald D. Nash, *World War II in the West: Reshaping the Economy* (Lincoln: University of Nebraska Press, 1990) 25-6.

[26]Nash, ibid. ,20- 1.

[27]Irwin D. Hoffman, "Commentary," *Irwin D. Hoffman, An Artist's Life* (Boston: Boston Public Library, 1982) 49.

[28]Nash, World War II, 20.

[29]Arnold Hoffman, "Interim Report," March 6, 1943. Hoffman Collection.

[30]Almost all the details of life in the camp and its inhabitants were derived from a lengthy series of interviews and correspondence from 1985 to 1989 with Phil Blazovic, mine superintendent, and Jack Frost, prospector and later operator of the calcite mine.

[31]Irwin D. Hoffman, "Commentary," 42.

[32]This demonstration was witnessed and corroborated by both McCulloch and Blazovic. When the latter took Salvador to a physician to be treated for severe burns on his forearms

from a hot Barco, he asked him half-seriously why hot coals did not affect him but the Barco did. Salvador's response was, "when I work for white man, I use white man's medicine; your medicine is no good!"

[33]E. W. Newman, "Methods of Prospecting and Mining Optical Calcite in Montana," *Mining Technology.* (New York: AIMME, November 1945) T.P. 1896.

[34]Irene Kirscher (Letter, September 10, 1986) supplied most of the details about the inspectors and their training with Berman.

[35]Florence Armagost, Office of Montana Secretary of State (Letter, March 20, 1990) states that Crystal Cutters was incorporated under the Laws of the State of Montana on August 9, 1943 and that the corporation was dissolved on November 3, 1943.

[36]Harry Berman (Letter, November 8, 1943, Hoffman Collection) wrote the Naval procurement officer for the ORS in dismay over his futile efforts on behalf of calcite which stole his time and attention from the military quartz program. Tragically, he was killed a short time later in the crash of a military plane in Scotland while on a quartz mission.

[37]Clinton J. T. Young (Letter, October 15, 1942) wrote the officer at the Bureau of Ordnance in charge of the ORS program asking him to identify a government agency to handle procurement of calcite from the Hoffmans.

[38]McCormick, "History," 143.

[39]Simon D. Strauss (Letter, January 12, 1987) describes the Hoffmans as hot-headed, given to intemperate language, [and] highly opinionated."

[40]McCormick, "History," 149. Wade sued first Polaroid then Calcite Operators for about $160,000, the difference between $30 per pound and his 50-cent royalty on every pound of crystals removed from his property. Later, he was convinced the value was $50 per pound on the strength of a rumor he heard from Oregon.

[41]It was a Pyrrhic victory for Wade. His Draft Board was in New York City, Hoffmans' home territory. By a strange coincidence, Wade's deferment was canceled and he was drafted immediately after the Hoffmans were pushed out of Clyde Park. Robert Hoffman had openly questioned Wade's deferment ("he's a 'fancy' skater, not a rancher") and Wade thereafter believed Hoffman responsible for the draft call. Wade later retaliated by instigating an FBI investigation of the Hoffmans' operations in Montana.

[42]McCormick, "History," 153.

[43]Irene Kirscher, Interview.

[44]Newman, "Methods of Prospecting."

[45]Stoll and Anderson.

[46]Jesse C Johnson, "Digest Report on Optical Calcite Contract AA-252." (Washington, DC: National Archives, 1944) RG 242, Records of the War Production Board.

[47]Carl Fries, Jr., *Optical Calcite Deposits of the Republic of Mexico.* (Washington: GPO 1948). US Geologic Survey Bulletin 954-D: 149-150.

[48]Cordell Durrell, "Geology of the Quartz-Crystal Mines Near Mokelumne Hill, Calaveras County, California." *Report XL of State Mineralogist.* (San Francisco: State Department of Mines, 1948): 423-433.

[49]Hugh H. Waesche, "Quartz Crystal and Optical Calcite," *Industrial Minerals and Rocks.* (New York: AIMME, 1960), 687-698.

[50]Lewis Orrell, "Mining California Calcite Crystals for the Optical Ring Sight," *California Geology* (Sacramento: California Division of Mines and Geology, March 1993): 45-49.

[51]Vino Vato (Interview, 1992), officer of the Carl Lambrecht Co., Chicago.

[52]_____, US. *Naval Administration in World War II: Bureau of Ordinance.* Part II, The Navy's Ordnance; v5, Fire Control (Except Radar) and Aviation Ordnance. p381.