Mining the Salar Grande

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ABSTRACT

The Marcona Corporation, an international mining and shipping organization, with its affiliate Compania Minera Santa Adriana, S.A. is developing major rock salt production facilities in Northern Chile. The mine is located on the Solar Grande Deposit approximately 30 kilometers inland from the harbor of Patillos and about 80 kilometers south of Iquique, Chile. The salt deposit has an exposed surface area of approximately 500 square kilometers. Reserves of high purity rock salt are in the billions of tons. Open pit mining methods are employed for removing the salt, which is currently transported by truck to Patillos for crushing, screening and stockpiling. All of the salt is shipped by ocean going bulk carriers. Shipments have reached the 1,000,000 ton per cent range and are divided between North and South America and Japan.

In 1967 the Marcona Corporation of San Francisco, California, purchased an interest in the Compania Minera Santa Adriana S.A. organized by Osvaldo and Alfonso F. de Castro of Santiago, Chile to develop rock salt production from the Salar Grande, in northern Chile. Marcona's interest in Santa Adriana was increased to almost 75% during the year of 1968.

Interest in the Salar Grande by the founders of Santa Adriana dates back nearly 60 years to early exploration work which revealed this immense deposit of high purity rock salt. However, at that time their efforts were directed toward a search for potash and consequently the salt discovery was not immediately pursued or probably even treated with much enthusiasm.

Since the original discovery, small mining operations have been attempted on the Salar by various groups and companies. Prior to 1967 most of the salt produced was consumed by local Chilean requirements and very little had been exported. The advent of the super bulk carrier since World War II, and the development of international type organizations with vertically integrated expertise in production, transportation and marketing has finally opened the door for large scale development of rock salt production from the Salar Grande.

The Salar Grande is located in the Atacama Desert which lies between the Pacific coast and western slopes of the Andes and extends over a major portion of Northern Chile. The desert consists of moderately high table lands at 2,000–3,000 feet of elevation relieved by northerly trending ridges or low mountain ranges and interior basins or pampas. The seaward face of the desert land mass is defined in some places by a coastal range and in other places by a steep escarpment. In a few isolated spots there exists either an alluvial fan or a sufficiently wide beach to permit a townsite and harbor development between the escarpment and the sea.

Iquique, one of the few inhabited points on the north coast, is the nearest major town to the Salar Grande. Iquique has a population of about 70,000 and is the capital of Tarapaca, the northern most province of Chile. It is historically known as a major port for the nitrate industry.

Iquique is about 50 miles north of the northern end of the Salar Grande. The Salar extends another 30 miles to the south with an average width of about 5 miles. The westerly boundary of the Salar is 8 to 12 miles inland from the Pacific Coast. It is

at an elevation of approximately 2,100 feet and is separated from the coast by either coastal range or steep escarpment varying in elevation up to 3,000 feet.

Forty-two miles south of Iquique is the bay of Patillos which affords a natural, deepwater ship anchorage. Also the beach area at Patillos is very broad and is ideal for plant, stockpiling and townsite facilities. Fourteen miles southeast from Patillos is the open pit rock salt mine being developed by Santa Adriana. The mine is locally known as the Salina Bahia Blanco.

Perhaps the most striking feature of this area is its arid climate. It is an absolute desert, barren and devoid of any signs of natural vegetation. It is among the driest regions of which there is any record. The average annual rainfall in Iquique over a 21-year period is recorded as 1.5mm or about 0.06 inches.

The temperature on the coast is affected by the cold Humboldt Current which flows from 41°S Latitude, northward along the entire coast of Chile. Consequently, the mean temperature at Iquique is only 66°F. Inland on the Salar Grande, and away from the stabilizing affect of the ocean, the temperature can fluctuate as much as 60°F between the daytime high and nighttime low readings.

While the average recorded rainfall is practically zero, there are very heavy fogs during the winter which enshroud the coast and penetrate inland to cover the Salar. The effect of the moisture from the fogs is evident by the visible surface dissolution of the Salar.

Heavy rain and snow falls occur in the Andes above an elevation of 8,000 feet along the eastern boundary of the Atacama Desert. The runoff of this precipitation and the resulting dissolution of water soluble salts, could have over a significant period of geological time provided some support for the popular explanation behind the deposition of the Salar Grande rock salt. The proposition can also be applied to the occurrence of nitrate, sodium sulfate, calcium sulfate and other chemicals common to the many Salars of the region.

The Salar Grande can be considered as the westerly arm of a vast U-shaped basin. The Salar de Llamara forms the southern section of the "U" and the Salares de la Sur Viejo, Bueno Vista and Pintados make up the great easterly arm from south to north respectively. The surface elevation decreases by about 1,500 feet through the U-shaped basin from the north end of the Salar de Pintados or easterly arm, to the north end of the Salar Grande or westerly arm.

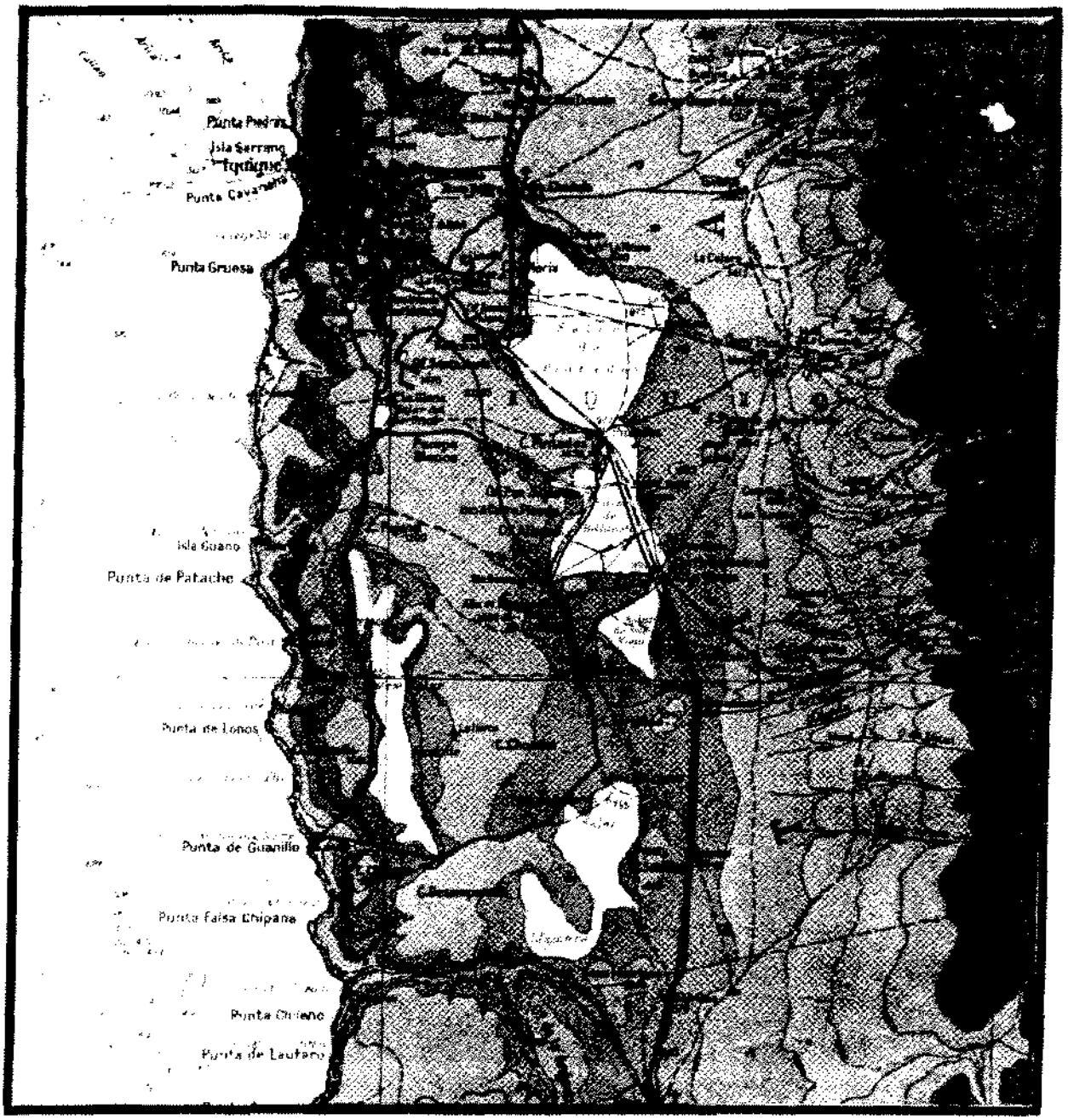
Pre-historic runoff from the Andes traveling west and carrying dissolved salts could have conceivably traversed through this giant pampas system extending 76 miles from north to south and 32 miles from east to west. As evaporation increased and the solutions became proportionately more concentrated, crystals of almost pure sodium sulfate, sodium nitrate, calcium sulfate and sodium chloride could have been selectively deposited. Such a process could have provided the major deposits of sodium sulfate and sodium nitrate of the Salar de Pintados. It could also account for the deposit of anhydrite and gypsum further to the south in the Salar de Llamara. And finally it would also account for the deposition of sodium chloride ithe Salar Grande.

The thickness of the salt deposit at the Salar Grande varies up to a known maximum of 450 feet. The surface of the Salar, while appearing flat, actually undulates, affording variations in elevation of as much as 30 or more feet. The entire surface is uniformly covered with football size nodules of salt, one per each 3 or 4 square feet. The nodules as well as the intervening surface area are covered with a thin layer of hard-baked reddish clay. The clay surface between nodules is dished and cracked from repeated cycles of wetting and drying. The salt nodules are rounded from dissolution by the regular occurrence of winter fog and the possible runoff from the extremely infrequent rain storms. The clay surface of the Salar appears to have been water deposited from the surrounding, low rounded mountains during the infrequent prehistoric rains. Scars of erosion, alluvial fans and big boulders are all evident at points along the beach surrounding the Salar.

Throughout northern Chile, there is ample geological evidence of faulting resulting from the uplifting of the Andes, the peneplain and the present coastal range. The frequent occurrence of earthquakes in recent years offers further evidence that the uplift continues even today and that the area is far from stable. This dynamic geological activity has contributed to a bi-directional system of vertical fractures in the salt of the Salar Grande.

The moisture from the fogs and infrequent rains has penetrated some of these fractures and deposited thin vertical seams of clay to varying depths. The seams vary in thickness to a maximum of one-half inch and most of them terminate less than 40 feet from the surface of the Salar.

The occurrence of clay gives the salt a reddish brown cast along the fracture planes in the upper 40 feet of the deposit. The salt mined from below the 40 foot depth is extremely white and



MAPA DE LOS SALARES

PROVINCIA DE TARAPACA

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crystalline in appearance. Early attempts at mining resulted in the handpicking or sorting of the upper section to create a white salt. Since the production was low and the mine was not sufficiently developed in depth this practice was not only feasible but necessary.

Developments in the mining and marketing areas now permit the production of two types of salt. The upper 40 feet which is reddish brown in color is now selectively handled to produce a high quality road salt. The white salt mined from below this depth is produced as a chemical and industrial salt.

Both types of salt are crushed and screened to meet the ASTM specification for road salt and as a result have similar structures. However, chemical characteristics vary somewhat between the two types of salt, as illustrated by the following typical analysis:

	Road Salt	Chemical-Industrial Salt
NaCl	98.80	99.37
Moisture	0.03	0.03
Na_2SO_4	0.49	0.28
Ca_2SO_4	0.17	0.17
$MgSO_4$	0.03	0.03
CaCl	0.00	0.00
MgCl	0.00	0.00
Insolubles	0.48	0.12

Since the two types of salt are produced the open pit mining methods have been refined to involve a system of benches which permit the selective mining of either road salt or industrial chemical salt, within the present pit depth of 118 feet.

The top four feet which contains the greatest clay occurrence is treated as an overburden. It is stripped off and wasted. The remainder of the clay occurs primarily in the next 36 feet. Therefore this depth is mined for road salt in two benches each 18 feet high. The third bench is 26 feet high and is mined selectively for either road or industrial chemical salt depending on occurrence of clay seams and its general color and appearance. The fourth and fifth benches each have a vertical height of 26 feet and are mined for industrial chemical salt, since the color and crystalline appearance is excellent.

All benches including the stripping bench require drilling and blasting. They all drill easily and penetration rates of up to 15 feet per minute are achieved. Therefore a large number of holes of small diameter on a close pattern can be employed economically to limit the minimum as well as the maximum sizes of the fragmentation. This practice is also complementary to the vertical fracture pattern. Attempts at a more open pattern have resulted in huge boulders, which have shifted out from the face along the fracture planes resulting in a high percentage of costly secondary blasting. The close pattern increases the probability that at least one blast hole will fall in each block formed by the fracture planes.

The present drillhole diameter is 2.5 inches and the pattern is 5 feet X 7 feet. A mixture of ammonium nitrate and fuel oil is used as a blasting agent. One eight inch stick of sixty percent gelatin is used as a primar, placed about six feet below the collar of each hole. Five and nine millisecond delays are used in conjunction with primacord to detonate the blast.

One feature of the operation which differs from most underground salt mining is that the conventional undercutting operation has been avoided. The added flexibility in determining the optimum dimensions for the blasts, free from the consideration of undercutting is a great advantage. However, extreme care must be given to drillhole depths in order to maintain bench elevations. Also, varying amounts of sub-drilling must be employed to control the toe of the newly blasted face. Fine salt from the blast is left on the bench after the normal loading out operation. It is then spread and watered to create a smooth road surface for the haul trucks, loading equipment, and drill rig.

Following blasting, the loading out of the broken salt is accomplished by two articulated, 6-1/2 yard, rubber tired front end loaders. The mobility of these machines is a great advantage in the development of the mine, since the available working places per bench are still somewhat limited. Under these conditions the front end rubber tired loader has a distinct advantage over the traditional power shovel.

The present primary crusher is located at the port of Patillos, 18 miles by road from the mine. Transport from the mine to Patillos is accomplished by tractor and rear dump trailer type truck units. Careful attention to the pit roads permit these heavy duty highway type trucks to travel to and from the mine face for direct loading by the front end loaders.

The present company owned truck fleet includes 19 tractors and 15 trailers, each unit has a carrying capacity of 28.5 long tons. The normal round trip cycle time from the mine to Patillos, a total distance of 36 miles, is 2 hours.

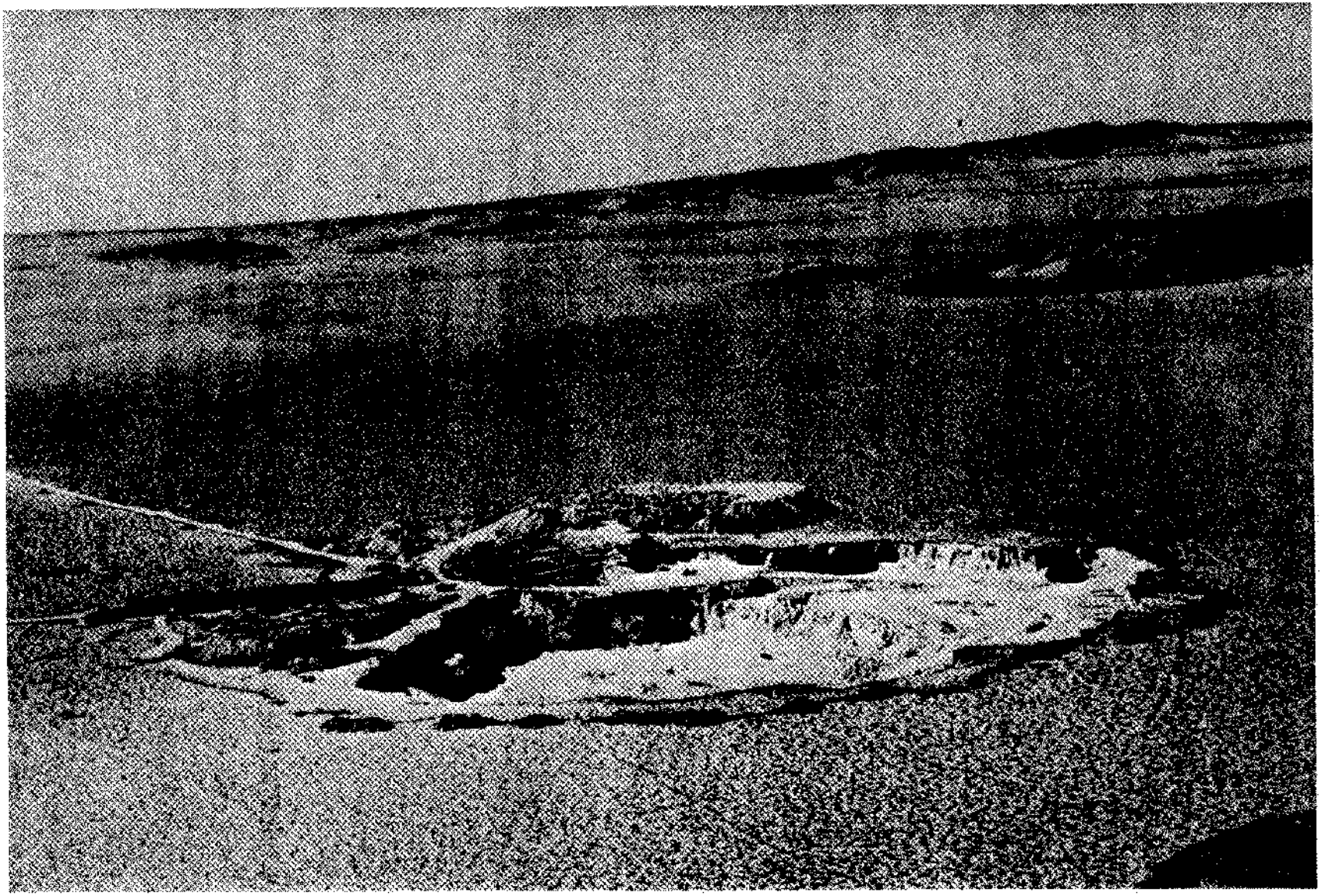

Exhibit 8—Salar Grande Showing Santa Adriana Mine Workings.

A limited number of contractor owned trucks are also employed in the total transport effort. This arrangement permits a degree of flexibility in meeting extra demands for production as well as in facilitating truck overhauls and special maintenance work.

The truck haul is perhaps the most difficult phase of the entire production effort. The 18 mile long road, while paved, is narrow and contains approximately 65 curves. These features along with the six mile long downhill run through a narrow twisting canyon and then along the face of the escarpment require the driver's absolute attention. The emphasis on safety is continuous and directed to every quarter, including driver training, equipment maintenance, reflection type road markers and road maintenance. Daily road patrols by transport supervision contribute to the overall safety and continuing improvement of the operation.

The truck haul operates on a two, 10 hour shift basis. Approximately 50 to 55 drivers including contractors' men are involved in the operation. The logistics for the necessary repair parts and components is also taxing, requiring in some cases up to six months lead time in the planning and anticipation of truck repair and overhaul work.

The transport operation terminates at the port of Patillos, where the primary crusher is located. The existing primary is a 32 × 40 inch jaw crusher. The maximum size discharged from this crusher is 3 inches. After crushing, the salt is fed to the screening plant which consists of two double deck 5 × 14 foot coarse screens, one single deck 3 × 6 foot coarse screen and two single deck 4 × 10 foot fine screens. The oversize from the coarse screens is reduced by hammermills and the discharge is recirculated through the screening plant. The screened salt in four different size ranges is collected in bins beneath the screens. Trucks are used to haul the salt from the bins to the stockpiles. The fines are rejected. The coarser salt from the remaining three bins is trucked to either the road salt or chemical-industrial salt, shipping stockpiles, depending on which salt is being processed.

The salt is reclaimed by two 10-yard rubber tired front end loaders for shiploading. These machines plus the fresh salt trucked concurrently from the screening plant provide shiploading rates of up to 800 long tons per hour. A shuttle type conveyor with a boom which can raise and lower is used at the end of a 367 foot conveyor extending from the shore to place the salt aboard ship. Since the wind direction, swells and currents are remarkably uniform and not severe, an anchorage system rather than a dock mooring system has been developed to secure ships during loading. Two sets of three anchor buoys each are located for bow and stern lines. The ships can be shifted to permit loading in different hatches by pulling in or letting out line. The system is extremely simple and practical and involves a minimum capital investment.

The present plant and mobile equipment are now producing at a rate in excess of 1,000,000 long tons per year. Plans have been developed and equipment is now being selected for the next phase of expansion. These plans include a new crushing plant at the mine featuring a 4 foot by 6 foot single roll primary crusher, secondary crusher and stockpiling facilities. At the port an expansion of the screening plant is anticipated along with a belt conveyor system for stockpiling. A little further in the future is an overland belt conveyor from the top of the escarpment to the port screening plant to shorten the truck haul by six miles or about 33%. The downhill haul is the most expensive portion of the entire route and its elimination will have a significant beneficial effect on operating costs.

The Marcona Corporation, through its wholly owned subsidiary, San Juan Carriers, Ltd., has a total ocean shipping capacity of about 2,300,000 DWT, and in 1968 moved approximately 15 million tons of iron ore, coal, salt, alumina and crude oil. This capability can also be expressed as 115 billion ton miles of ocean transport per year. Seven company-owned ships, 12 term-charter ships and up to 20-25 sailings per month on a voyage charter basis, combine to make this one of the largest dry bulk commodity fleets in the world.

Marcona has pioneered in the development of the multi-purpose type hull in which dry cargoes of varying bulk density such as iron ore, coal, grain and salt or liquid cargoes of oil can be economically transported in the same vessel on alternate voyages. Today Marcona is developing a slurry ship which will, as its name implies, receive and discharge a cargo of iron ore, coal or salt to a chemical user, in slurry form. This development will eliminate the need for the expensive, traditional type port discharging facilities.

Marcona's present company-owned fleet consists of ships having capacities from 52,000 to 106,000 deadweight tons. Two 130,000 DWT combination ore/oil carriers of the Vanguard class will be delivered in December of this year, and a third is scheduled for delivery early in 1970. These super ships will be used primarily for iron ore and crude oil. In contrast, plans are being formulated for a

Exhibit 9—Patillos Salt Stockpiles and Shiploading Facilities Shown During the Loading of a 50,000 Ton Carrier.

special salt carrier which may have a capacity in the intermediate range of 55,000 DWT.

The Marcona knowledge of shipping and its extensive maritime resources place it in a unique position among salt producing companies. It also satisfies one of the most vital requirements for the present and future success of the exploitation of rock salt from the rather remote Salar Grande.

Marcona affiliated companies market iron ore, salt and bulk commodity shipping services. Market and shipping coordination services are provided through offices located in New York, London and Tokyo.

The Salar Grande salt is currently being sold to the chlorine and caustic soda industry in Japan and for the road salt market along the East Coast of the United States; two major markets, on opposite sides of the world, 9,000 miles apart, and between 4,000 and 10,000 miles from the source of production.

Less than 10% of the current production of Salar Grande rock salt is consumed in Chile. Therefore the formula which has finally unlocked the Salar Grande is the great opportunity afforded by a world wide market, and the economic ability to reach this market permitted by the recent immense advances in maritime technology.