Metropolitan Mining:
Institutional and Scale Effects on the Salt Mines of Detroit

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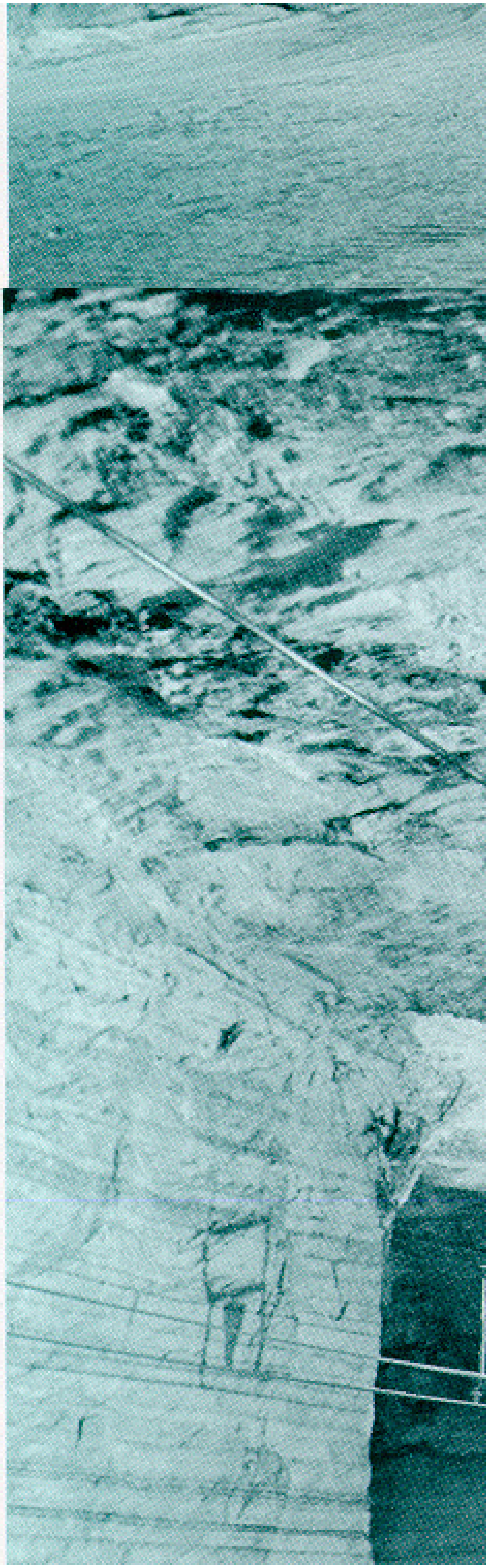
Revised June 1999; based on earlier work as noted at the end.

Abstract

Mining, as with most industrial activities, is constrained by logistics, which involves technological matters of transportation, material conversion and energy costs. Convention and law also influence the activity. These are institutional matters involving mineral rights and access to resources. Both logistical and institutional configurations exist in a space/time context and in metropolitan areas, where geographic space is a complex mosaic of private and public property, the limits to an industrial activity are nicely illustrated in the example of the salt mines of Detroit.

Introduction

Metropolitan mining refers to industries that extract minerals or other materials from locations within highly urbanized regions. The example of a metropolitan mine in Detroit reveals some interesting interplay between technological and institutional constraints. Industrial activities operate in a space/time envelope partially confined by logistics, the physical task of moving people, things and energy through space and time. Physical movements depend on the speed and cost of transportation and communication--technological matters employed to overcome the cost of space. Social/economic behavior is also constrained by conventions; bound by abstract, imaginary barriers that establish entitlement and prescribe behavior--institutional matters that have temporal components associated with expectation and risk. Social behavior often has

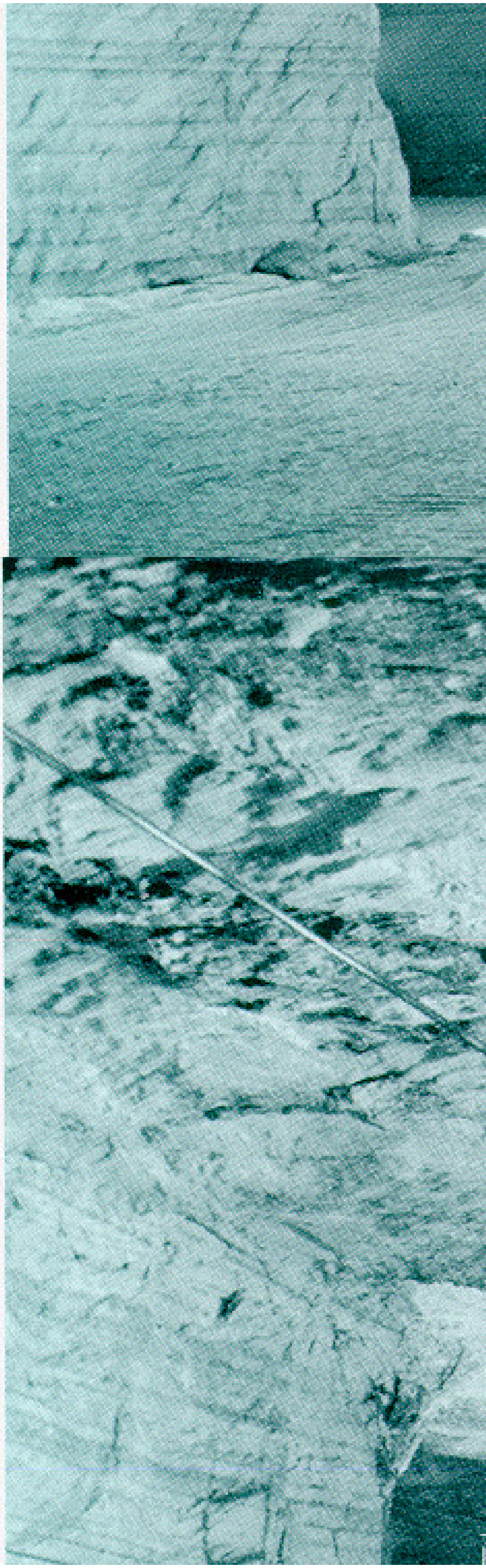


geographical manifestations. We know how to behave on account of where we are: on sacred ground, on private property, or in a public forum. Private property, although a very abstract and multi-dimensional concept, often includes strong geographical connotation. In this paper we make reference to one kind of private property, mineral rights used to gain access to the salt deposits under Detroit.

Every geographical process whether social or physical also has an intrinsic or operational scale associating relative size of the elements contained in the process. Two components are involved: (a) the diameter of the system which may be defined as the longest extent or distance between interacting parts and (b) the unit size or smallest extent of an elementary element. An elementary element is a part which is treated as a single unit in the system and which cannot be subdivided. This requires some elaboration. Everything and every action take some minimum time and space. We allocate time and space among activities according to their needs. We jostle about and shoulder one another aside to arrange our affairs spatially and temporally---that is geographically. If by chance or otherwise some elements cannot maintain their minimum unit size, they cease to exist, in Hägerstrand's words; everything has a minimum extent and duration, a kind of kernel or minimum unit of existence (Hagerstrand, 1970). This is true of abstract, institutional content of our environment as well as in the logistical matters we face. The interplay between space and time and scale are nicely illustrated in the Detroit Salt Mines of the International Salt Company.

The Geography of Salt Mining

The Detroit salt mine was started 1906 and finally closed operations in 1985 after millions of tons of salt had been removed. The work created extensive man-made caverns under the city that remain today. The Detroit mine has a rather complex shape that is intriguing to geographers and that calls for some explanation (Figure 1).



In mining the first issue is the matter of the location of the natural resource. As it happens salt deposits underlay much of the Michigan Basin and extend all across the Midwest into New York State. Anywhere in this region "straight down" carries one back in time. Nearly one quarter of a mile under Detroit we are brought back 390 million years into the Paleozoic Era to a Silurian Sea in which deep salt deposits were made in a series of layers now covered with shale, limestone and sandstone overburden. The Detroit salt mine worked a 30 foot thick seam of rock salt at 1135' below the surface, one of several layers of salt (Figure 2). The top 90 to 100 feet from the surface is unconsolidated glacial drift full of water under high pressure and permeated with hydrogen sulfide. This proved to be a difficult mix of material through which to drive a mineshaft.

The mineshaft was started in 1906 eleven years after the salt was discovered under the city. The mineshaft proved very difficult to dig and eight men lost their lives in the effort. By 1914 after bankruptcy and acquisition by a rival salt company the mine began production and shortly reached a production of about 10,000 tons per year. A second larger shaft 16 feet in diameter was sunk in 1922. Despite this width the largest opening is only 6 foot by 6-foot square as room for ventilation, the salt skips (the containers to lift the salt), power lines, elevators for men and equipment must all fit in the shafts. Both shafts were used. Large diesel trucks, front loaders, drilling rigs, conveyor machines, milling machine and machine shops to maintain them are all underground brought down the narrow shafts in pieces and even cut into pieces by acetylene torch and reassembled underground.

At a regional scale the location of the mine may be taken as market oriented. Because the resource is spatially ubiquitous, that is, available anywhere in the Midwest, proximity to the highest market potential dictates choice of location, hence the metropolitan location. There are only four rock salt mines in the northeast quarter of the country. Each is in a metropolitan area with an upstate

New York site as an exception. The cost of sinking the shafts appears too great for widespread use. For some decades there has been an alternative to open shaft mines. Brine wells are more common. In such installations the salt is removed by pumping hot water into the salt bed and withdrawing brine. Large Midwestern industrial users such as chemical companies can sink their own brine wells and are no longer customers for the rock salt mines. The overwhelming proportion of the rock salt is used to clear road of ice during winter months. That market is seasonal and varies with the severity of the winters. As it is always more efficient for an industrial operation, including mining, to have steady production, the older, closed parts of the salt mine are used for storage of processed salt. Storage is a time transfer process. The mine is very dry which means that the stored salt does not deteriorate over time.

The salt sells for about $18 to $20 per ton f.o.b. the mine. (f.o.b. means free on board--the customer pays for hauling it away). The mining company sells either f.o.b. or delivers and adjusts the price accordingly. They lease or contract for trucks from hauling companies when they offer to deliver. Transportation costs vary by size of truck, 25 cents per ton-mile for trucks with 10 to 15 ton capacity down to a minimum of 12 cents per ton-mile for truck/trailer rigs with 55 to 60 tons capacity. Great Lake carriers are much less, perhaps 3 cents per ton-mile. At these prices it doesn't take much distance to double the price of the salt: 167 miles by truck, 667 miles by water (Figure 3). The diagram gives some sense of when customer, principally municipalities, county and state road maintenance departments, will forego salt and turn to sand and plows to some other alternative to clearing streets in snow emergencies.

In 1960, the International Salt Company opened a new rock salt mine in Cleveland. It is located exactly on the shore of Lake Erie. This location has both logistical and institutional advantages. They are able to ship salt in bulk by lake carrier at much reduced costs per ton-mile than overland shipments. Cleveland is able to ship salt

past Detroit to lake ports in the upper Great Lakes at costs lower than it could be delivered from the Detroit mine. The Detroit mine has shipped by water in the past and is not much more than one-half mile from the turning basin of the River Rouge where they have loading facilities. This half-mile gap must, however, be bridged by trucking and loading costs that exceed the cost of the sixty-eight nautical mile shipment from Cleveland. The Cleveland mine also, by mining out under Lake Erie, leases mineral rights from a single owner, the State of Ohio. This permits a more efficient mine layout. In 1987 the Detroit mine ceased to operate, put out of business in part by its awkward shape. The Detroit Metropolitan area now gets its salt from Cleveland and Windsor, Ontario, where in the later location the mine is of optimal shape and extends out under the Detroit River on the Canadian side. In Canada, mineral rights laws were more favorable to the salt companies.

Site Conditions. Pure salt crystals make a very hard rock and hard rock mining techniques must be employed in the mine. The active mine face is undercut ten feet, (the undercut is called a kerf), powder holes drilled and the rock salt blasted free. Very large trucks, primary crushers, conveyor belts and milling machines all underground, are used to create the finished rock salt graded by several sizes. Up to twenty-five percent of annual production can be stored in the empty rooms of the mine (200,000 to 250,000 tons) as annual productions of up to one million tons are mined in normal years. The active face of the mine is 23 to 25 feet high and 50 to 60 feet wide. Eight hundred to nine hundred tons of salt are freed in each shot. Salt weighs about one ton per cubic yard in place. The seam being worked yields about 40,000 tons per acre of recoverable salt. These dimensions are important when we turn to considering technological and institutional scale effects in the mining operation. Long rooms, fifty feet wide and twenty-five feet high are formed by the mining operations. Huge salt pillars sixty by eighty feet on a side are left in place to hold up the roof. The salt is strong enough that no shoring is necessary. No cave-in

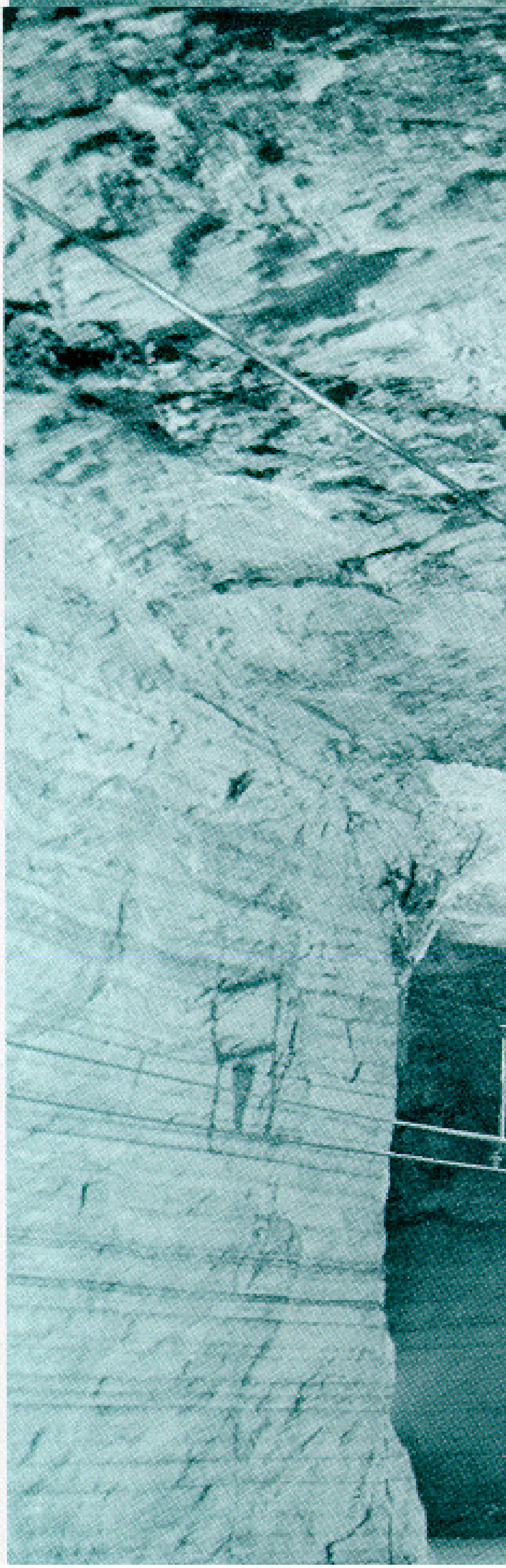
has ever occurred. This type of hard rock mine is called "pillar and room" (Figure 4). Sixty-two percent of the salt is recovered using this method. The mine has been operating since 1914. Something like 1700 acres have been excavated. Figure 1 shows a plane view of the mine as it exists today. These boundaries are not exact because the mine managers were reluctant to release a map of the mine to me for reasons that will become obvious as I continue this story. Notice the irregular shape of the mine and that it extends essentially only westward from the mineshaft. This does not make sense technologically. Logistics are a big part of the mining costs and logistically the best shape would be compact, nearly circular with the mineshaft at the center. Two transport technologies are employed underground, trucks costing at best perhaps 20 cents per ton-mile and conveyor belt at perhaps eight cents per ton-mile. The spatial problem is to minimize the sum of these two costs from the active mine face to the shaft. The radius of a circle of 1700 acres is 0.92 miles. The active mine face is currently over four miles away: 434% farther than the ideal. If half the distance were by truck and the rest by conveyor belt this distance would cost 35.3 cents per ton more than the ideal. For 800,000 tons per year that is an additional $280,000. So why does the mine have this shape? The answer is institutional and relates back to that concept of the kernel of existence.

This permits a more efficient mine layout. In 1985 the Detroit mine ceased to operate, put out of business by its bad shape. The Detroit Metropolitan area now gets its salt from Cleveland and Windsor, Ontario, where in the later location the mine is of optimal shape and extends out under the Detroit River on the Canadian side. In Canada, mineral rights laws were more favorable for the salt companies.

Mineral Rights and Transaction costs. In Michigan every landowner having free title to his or her land owns the mineral rights for all minerals beneath it. The salt company will offer around $2000 per acre for mineral right or about $0.05 per ton. This is highly variable depending upon the size and strategic position of the

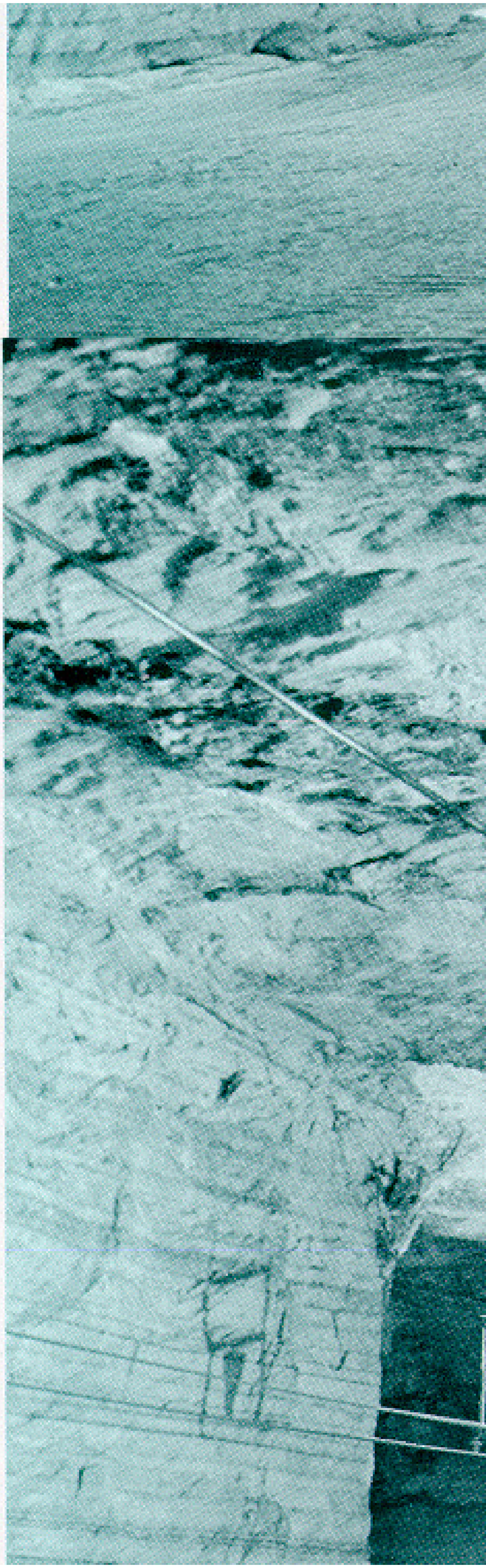
property under consideration. Under some circumstances the company might be willing to buy the land outright only in order to obtain the mineral rights. In other circumstances mineral rights would be worth very little. The size and location of the property is the key to its value. This can be understood through analysis of institutional factors. There is a minimum transaction cost associated with each mineral rights transaction. First negotiations must be made, and upon agreement, the transfer or leasing of mineral rights must be assigned in each property deed and recorded at the county court house records office. If two lawyers are involved, one for each side, there exists a minimum institutional friction for each transaction that in a rock bottom estimate would total more than one thousand dollars at ninety to a hundred dollars per hour per lawyer for a day or day and a half of work. It could be much more. If the legal fees were $1200, this translates into all the value of the mineral rights for a lot just under a two-thirds of an acre in size. Most city lots in high-density residential blocks are 1/8 to 1/6 of an acre in size. The mineral rights for a lot 1/6-acre in size are worth perhaps $333. Would you like to sell your mineral rights to the salt company? Never mind that your lawyer would probably get most of this payment.

There is another problem. Time as well as space is involved. For security in continuity of operations the company is interested in procuring mineral rights ten years or more in advance of actual use. That means that they are not willing to pay more than the present worth for the mineral rights they will use in ten years. For a lot that has about $400 worth of mineral rights--a lot 91 feet on the side or just under 1/5 acre, the present worth at 5.5% interest rate is $234 -- perhaps under two hours of a lawyers time. Under these conditions, the salt company preferred to take options on the mineral rights and promise to pay royalties whenever they actually mined under your property. Under this arrangement they were willing to offer to pay $2000 per acre in ten years or so, and to make cash payments as the salt is mined. The seller needed to evaluate this option based on the present worth of that future payment using the same interest



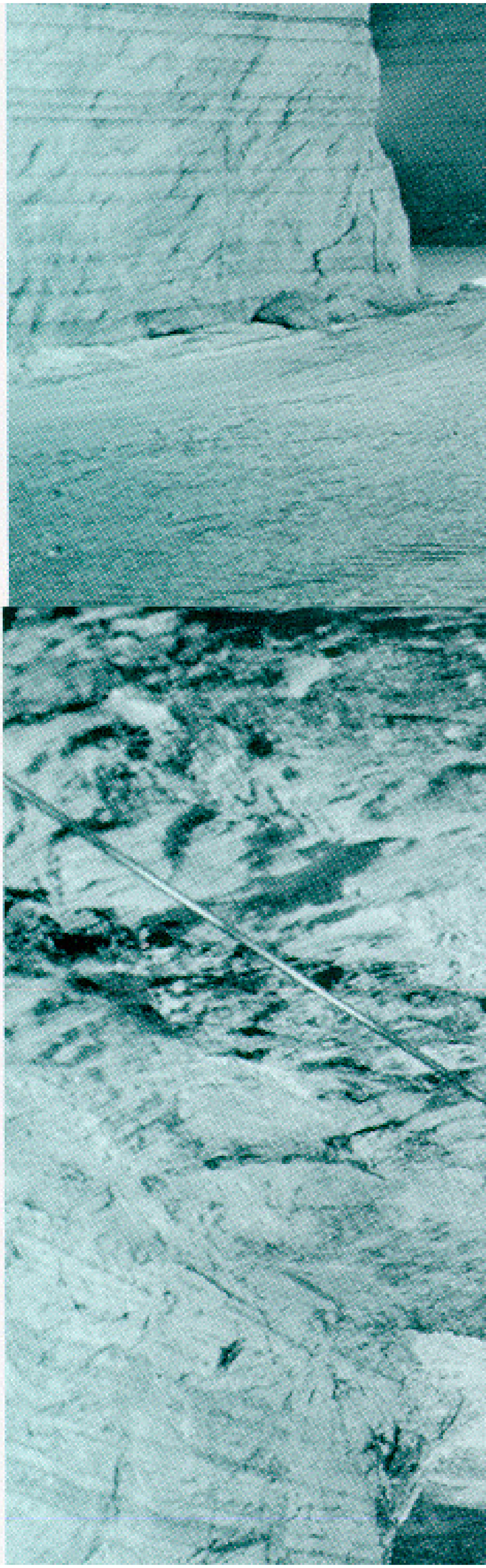
formula. For both parties the transaction costs (i.e., the lawyers' fees) had to be paid up front. There were also some accounting expenses associated with this procedure and again it did not pay to deal with small landowners--the mining company was not interested in anything under an acre, in fact, deals involving several acres at a time are clearly preferable. Therefore residential land use marks the limit to the mining activities. This is abundantly clear from looking at the map. The shape of the mine is understandable when considering institutional constraints in addition to technological ones. Although the mine management did not discuss the matter with me, some simple calculations are sufficient to give a sense of the minimum property size a metropolitan mining company would be willing to consider for acquiring property rights. The present value of $2000 for each acre of mineral rights to be used in ten years is $1171 at 5.5% interest. If legal and closing costs were to be kept at, say 5% of total mineral rights costs, then supposing an efficient law firm could handle the matter in one day, $800 worth of legal fees in current money would require a $16,000 transaction to be attractive to the mine operators, ($800 = .05P, P= $16000). The figure $16,000 divided by $1170.86 (present value per acre) yields 13.7 acres at 5.5% interest and 22.8 acres at 11% interest. The salt company would not be interested in any place under twelve or so acres with more normal interest rates and nothing under twenty-two acres given high interest rates characteristic of the 1980's unless some special strategic location existed that might affect mine operations. Both a unit space and a time duration, twelve acres and ten years, can be seen to affect the overall dimensions and actual shape of the mine.

There are more subtleties. Space and time combine to create velocity. The velocity at which things happen affects geographic patterns as well. Twenty acres are mined in a typical year amounting to 800,000 tons of salt. The tonnage must move from the active face of the mine to the shaft. Some time ago the company negotiated a purchase of mineral rights from a group of small lot owners in which all had to agree to the sale of



their mineral rights or no deal was to be made. The plan was to cut off about 3000 feet of underground travel route to reduce underground transportation costs. Diesel trucks with 22 ton load capacities are used underground along with conveyor belts. I estimate the diesels may cost 20 cents/ton-mile (I did not have exact figures from the salt company). A saving of 3000/5280 of a mile at 20 cents/ton-mile would be 11.4 cents per ton. A similar saving if the conveyor system were extended through the bypass would be 4.5 cents per ton. At 800,000 tons per year the savings in truck operating costs would be $91 thousand per year. An amount of $36 thousand would be saved if the conveyor system were shortened by this much. The bypass opened up approximately one-quarter square mile (160 acres), which if mined at about 20 acres per year would mean eight years of operation. What is the present worth of a stream of income (savings) of $91 thousand per year for eight years? The interest formula for an annuity or stream of savings for this period yields a present value of $576,000.

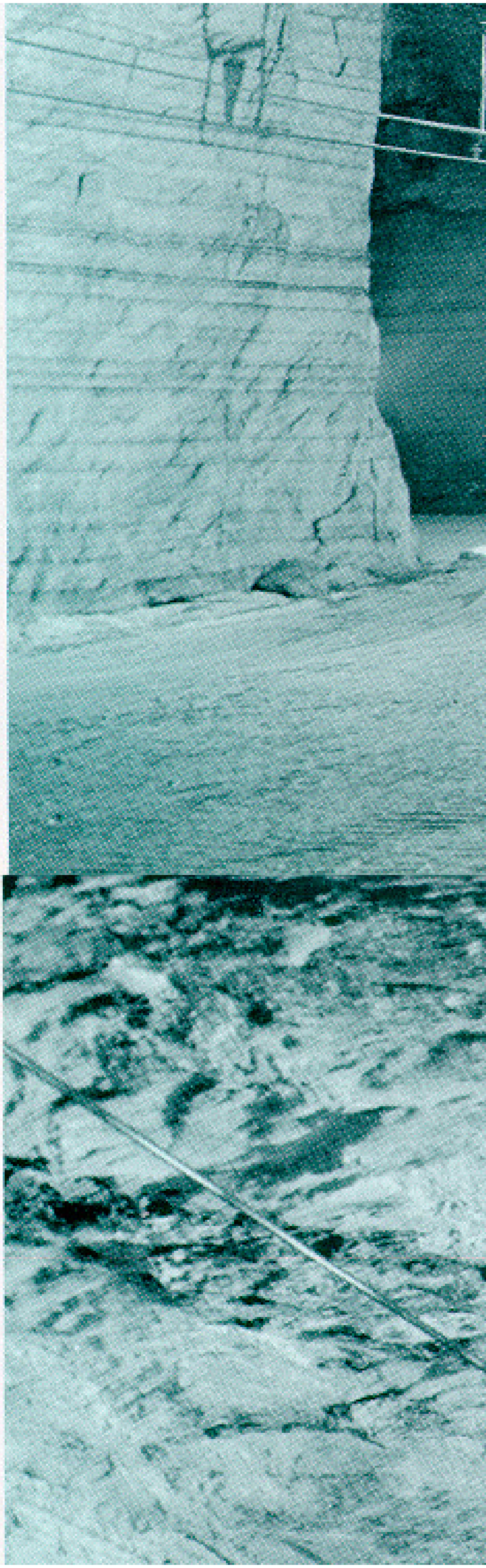
The bypass involved extending mining operations down a residential street where property owners on both sides owned the mineral rights to the center of the street. A corridor 200 feet wide and 1900 feet long was sought. The by-pass corridor is shown in Figure 1 located on the north side of the central part of the mine. It makes the shape of the mine more complex topologically by creating a hole in the shape. The corridor contains 8.17 acres. Using the truck technology, the by-pass was worth $70 thousand per acre in savings. The strategic location was thus worth thirty-five times the usual mineral rights payments. To realize this fact one must account for the effects of space and time simultaneously, that is, by considering the velocity of activities. Gross sales at twenty dollars a ton and 800,000 tons per year amount to sixteen million dollars. Savings of $91,000 by better spatial arrangement within the mine amounts to one half percent of the gross per year. I have no idea what profit margins for a mine of this sort amount to, but I suspect five percent of gross might be generous. Perhaps the corridor was worth ten percent of profits per year. It pays to pay attention to geography. The prospects for the



mine are good insofar as acquisition of property rights are concerned. The mine abuts parcels that exceed ten acres in size at several points on its perimeters. These in turn open up to territory several times the area that has been mined up to the present. The access was greatly improved once they acquired mineral rights under a railroad right-of-way and more recently under the Interstate Highway in the City of Allen Park. These linear forms create many links to large parcels under various industrial properties in these communities. I conclude that the mining company had opportunities for acquiring mineral rights sufficient to carry them well into the next century. The outside dimension and shape of the mine can thus be seen to be a function of an elementary element that would be no smaller than ten acres and which, in turn, depended upon institutional factors interacting with logistical considerations. Certain strategic locations might be exceptions.

Metropolitan salt mining may seem to be a rather special topic but I detect a generalization here that sheds light on how spatial and temporal parameters can be used in understanding other urban patterns. I have thought it odd that high-density town house developments have sprung up at the edge of metropolitan regions and unfortunate also because of the increase in travel effort this pattern creates. I suspect that changes in construction costs and in the working of the financial market have increased the size of minimum viable developments to the extent that suitable large properties can only be found on the edge of the metropolitan areas. The urban region is a mosaic, made up of discrete elements and not a continuous surface as is implied in certain urban models. When a system is made up of discrete units the minimum viable unit space for an activity affects the larger dimensions of the activity and should enter into calculations used to explain the general patterns.

In spatial terms alone the key variable is density of the activity measured in dollars per unit area. In temporal terms the key variable is the annual return on initial investments and transaction costs measured as an intensity or dollar amount per unit of time. In



simultaneous space and time the measure is dollars per unit area per unit time. Where/when there is a moving front as in the case of metropolitan mining or subdivision expansion, the key variable is a velocity or rate of advance. In discrete space/time, one must take into account an appropriate estimate of the minimum extent and duration of all elementary elements (kernels) in the system and their interactions.

References:

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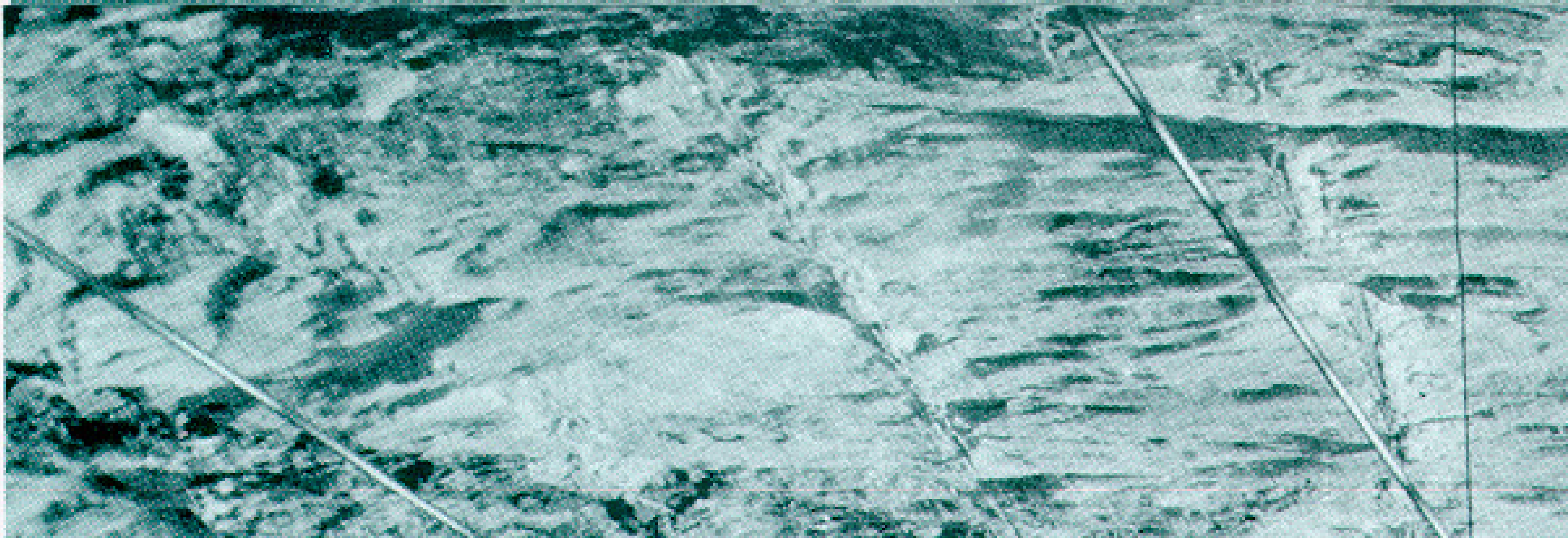
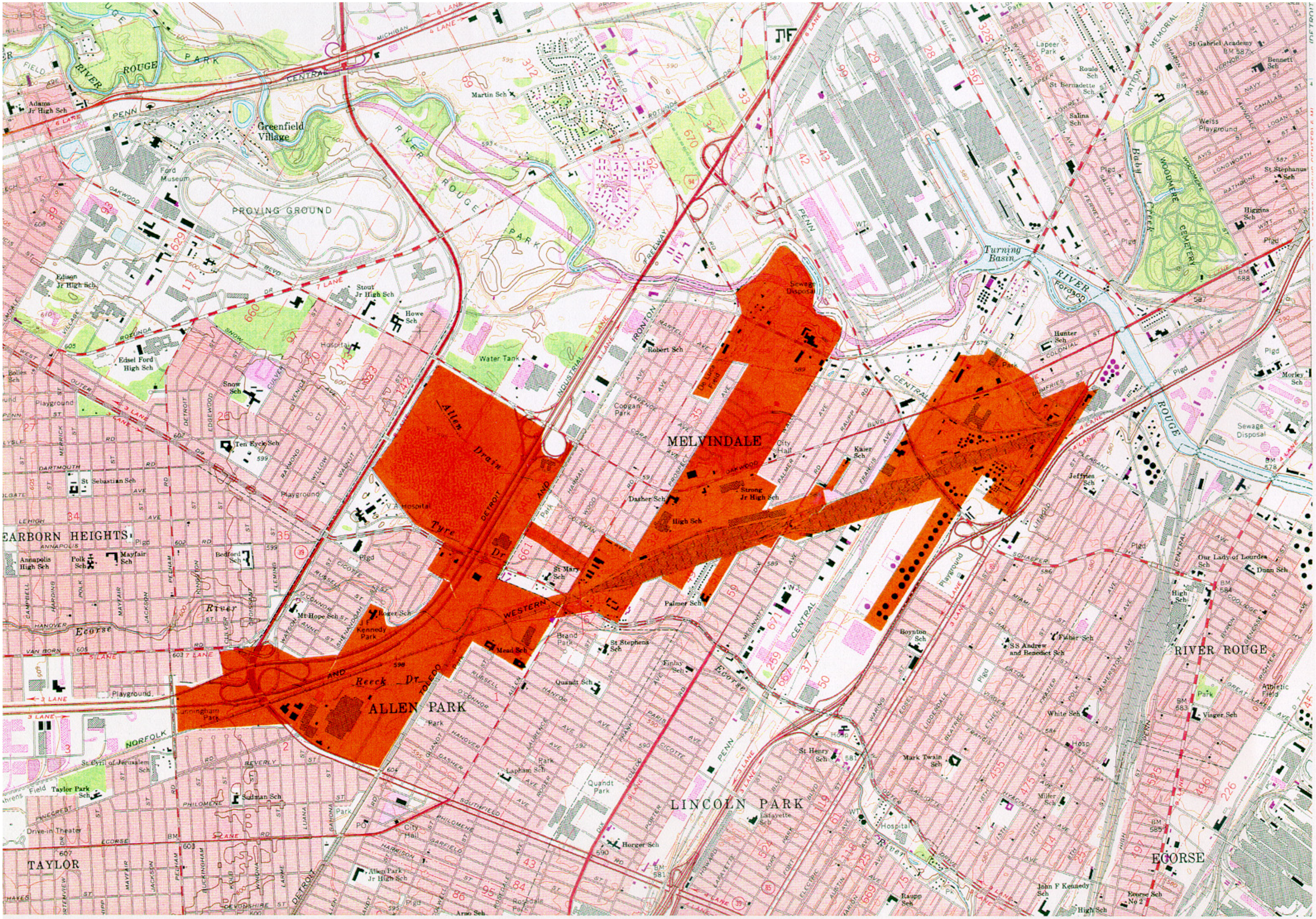
I extend thanks to Mr. Jim McDonald, the Manager of these mines, for the information he shared with me about their operations.

"Metropolitan Mining: Institutional and Scale Constraints on the Salt
Mines of Detroit", paper presented to the Northeast Regional Science
Conference, Hunter College, New York City, May 7, 1983.

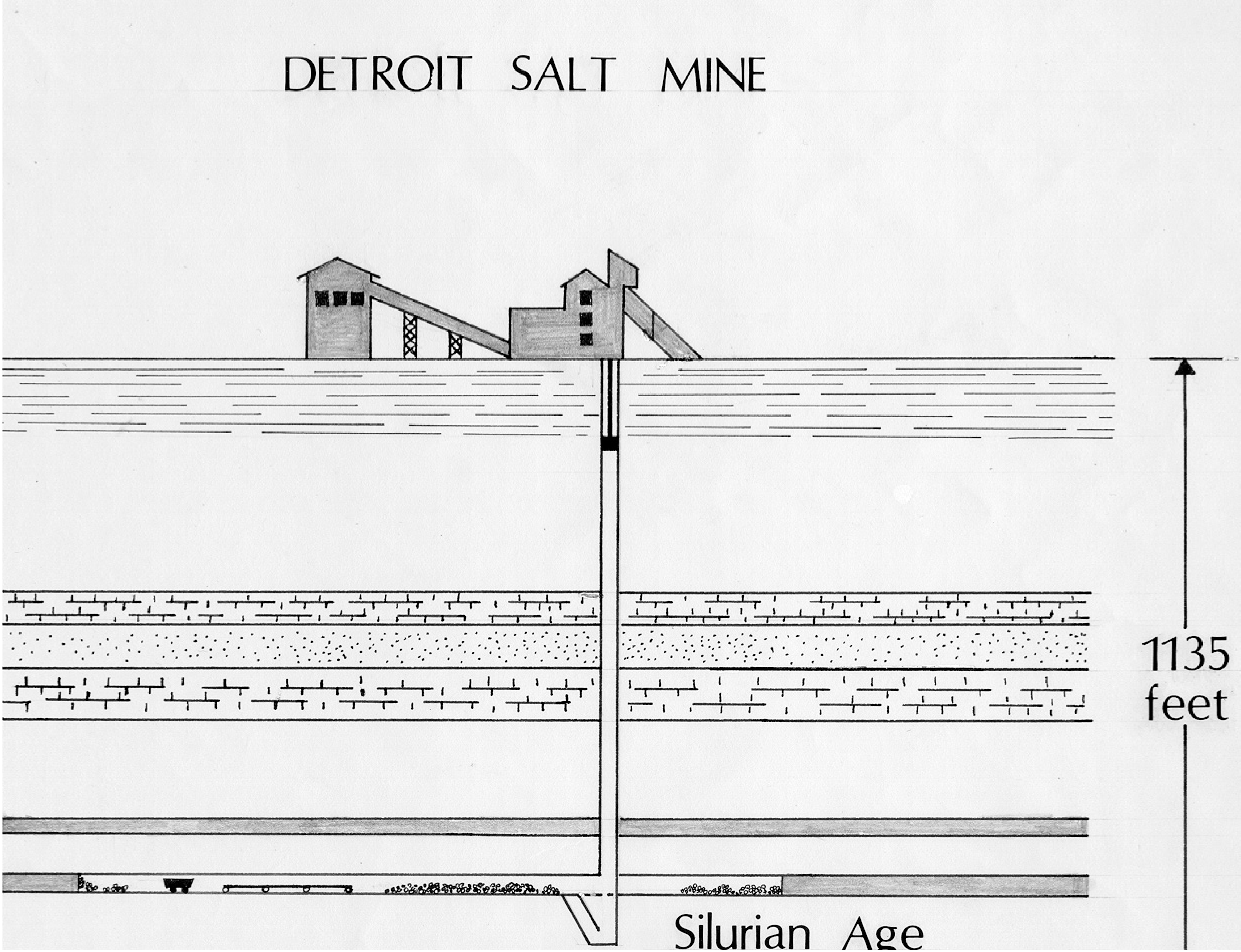
A version of the paper was also presented by the author as part of a
lecture entitled: "Place, Location, Time and Timing: Form and Texture in Space/Time" given as the Reginald G. Golledge Invited Lecture, Department of Geography, University of California, Santa Barbara, April 8, 1999.

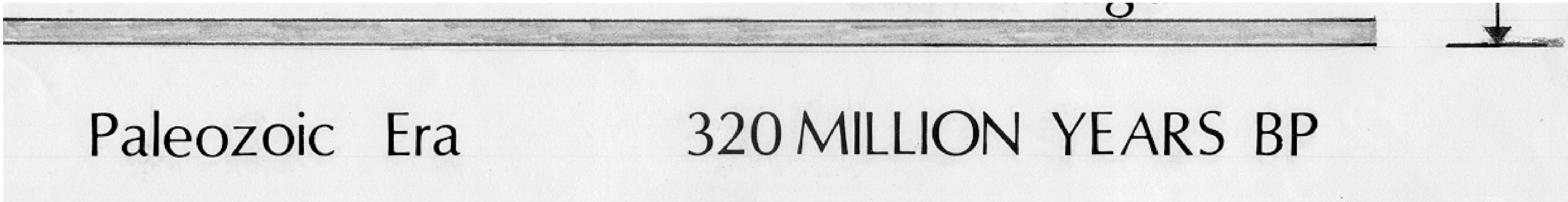


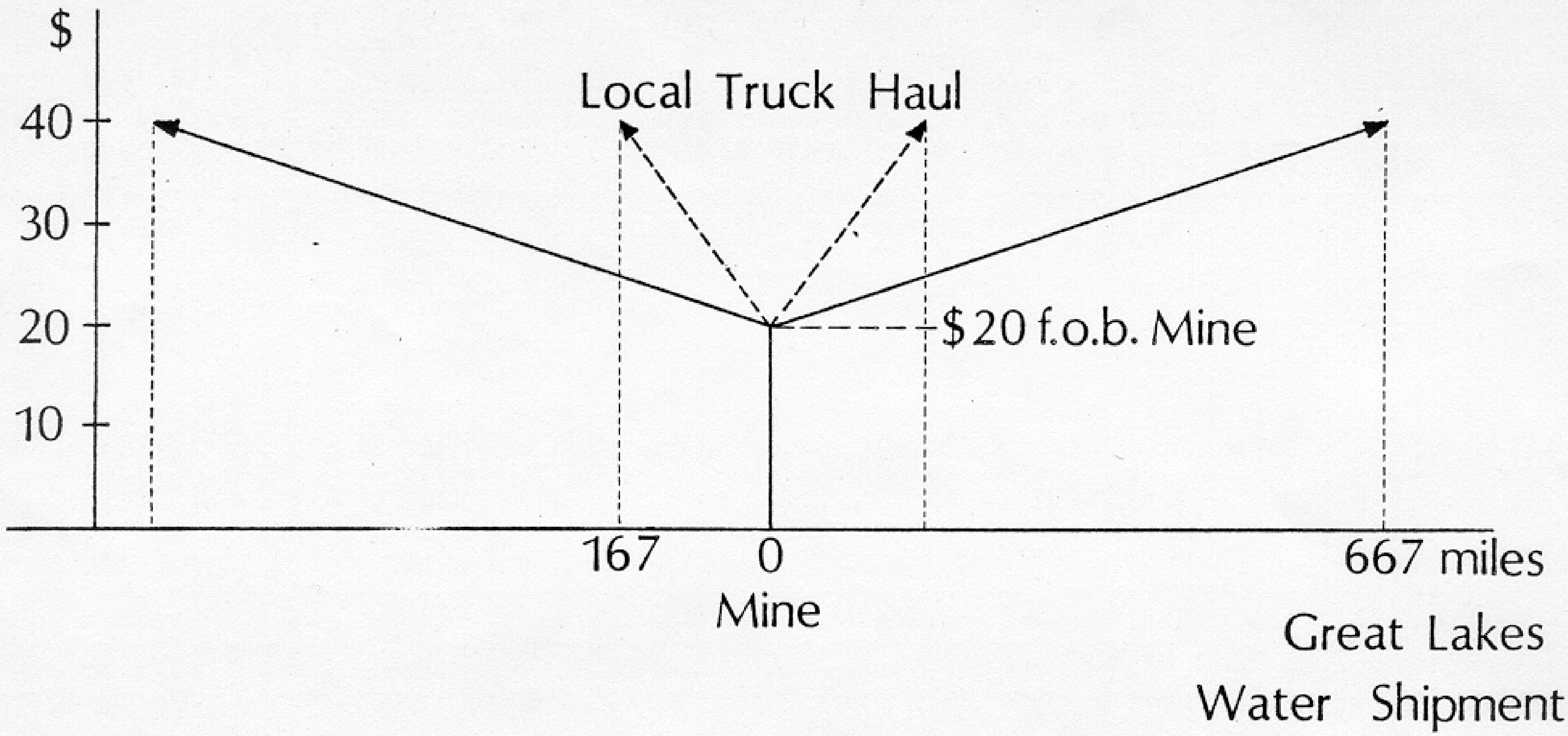


one mile

Detroit Salt Mine


DETROIT SALT MINE
1135
feet
Silurian Age


Paleozoic Era
320 MILLION YEARS BP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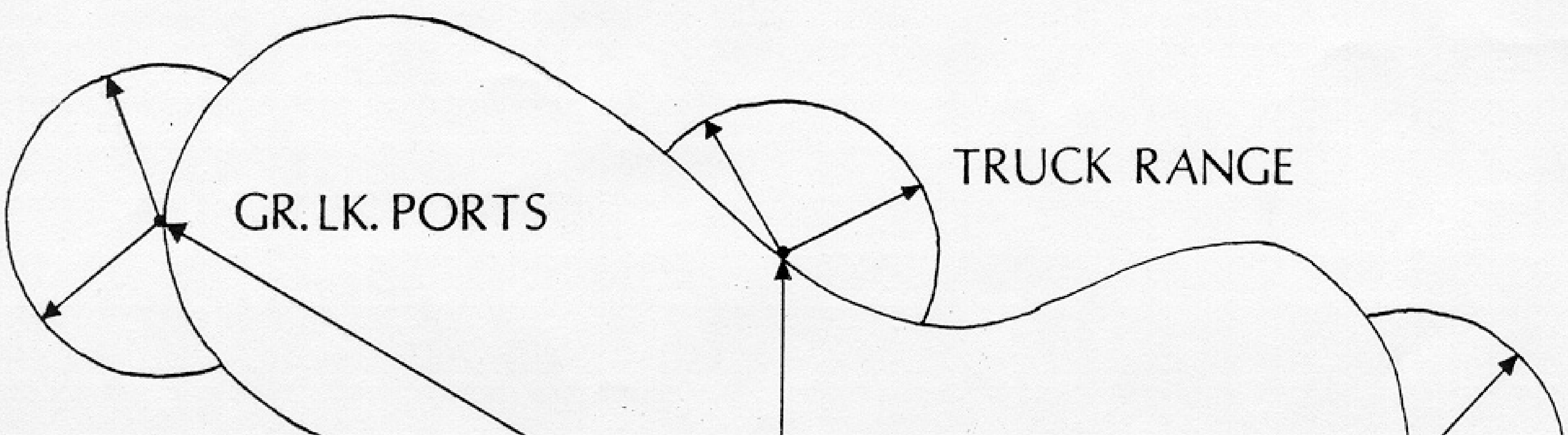
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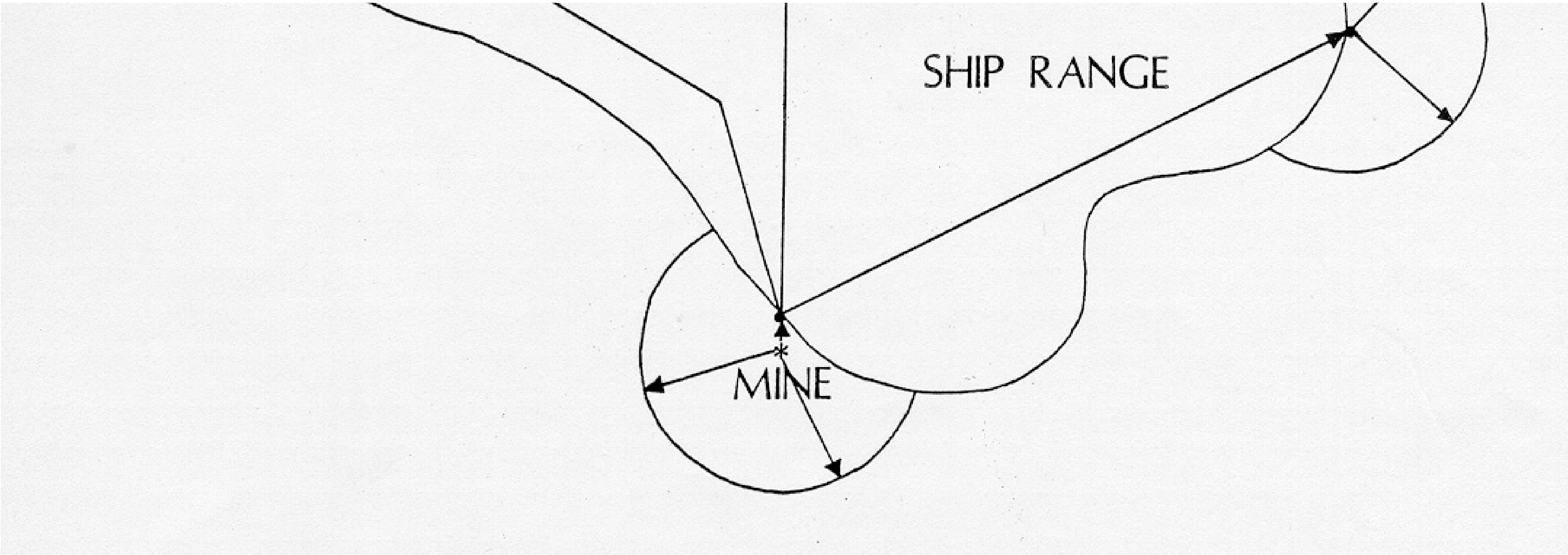
SHIP RANGE
MINE