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Developement work Proposals,

Julian Deposit

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D. M. Knowles

February 1968

Canadian Javelin Limited

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INTRODUCTION

The exploration work accomplished to date on the Julian deposit serves merely to indicate the general nature and size of the deposit. It does not permit classification of the deposit as a proven ore body consisting of a specific amount of ore at a known location with demonstrated metallurgical characteristics. More geologic, engineering, and metallurgical test evidence must be gathered, on a sample scale appropriate with the size of the deposit, before conclusions valid for mining and concentration plant design purposes can be made.

The physical nature of the deposit will present several operational problems, some of these are presently recognized, others will probably be discovered. The development work plan herein presented should provide the means of gathering the evidence needed to examine these problems, and also to accomplish some items useful for mine development.

BACKGROUND

The Carol and Wabush operations have gone through the exploration and development stages; they are currently in the process of refining techniques and expanding production capacity. A review of their experiences will be of value in considering the Julian development.

CAROL DEVELOPMENT

The Iron ore Company of Canada has always emphasized obtaining as much information about their deposits as reasonably possible; they believe in thorough geologic examinations and drill hole programs. Their exploration stage drill holes were at 400 foot intervals on lines 1600 feet apart. For development stage purposes, they used 200 foot intervals on lines 400 feet apart; with every third hole extending below the bottom of the intended pit to the bottom of the Smallwood deposit.

The Smallwood ore consists of non-friable, quartz-specular hematite-magnetite and accessory minerals in variable proportions. The unleached nature of the deposit permitted nearly complete core recovery and the core was used for grindability and concentration tests. Their sample-reserve figure is reported to be one 10 foot sample for each 33,000 tons of ore.

They adopted the strategy of conducting a minimal pilot plant operation, sufficient only to identify, solve and relate metallurgical behavior to the closely explored deposit, and confirmed by continuous operation on representative materials. The plant was a roughly built, temporary facility which treated about 50,000 tons of test pit material and about 13,000 tons of material from an adit driven into the Smallwood deposit. The 2000 foot long, 9 x 7 foot adit was driven in 10 foot rounds, with the approximately 63 tons of material from each round treated in sequence by the plant. Results were correlated with geology and drill hole samples. These ingestigations were the basis of their concentrating plant design.

The Carol plant was designed and built to handle ore from the Smallwood deposit, and upon commencement of operations there were no serious problems or abnormal situations of serious consequence. However, high magnetite content ore became a problem because of its slow grinding characteristics, and since commencement of the pellet plant, magnetite variability has been a constant problem due to its effect on the heat balance of the pelletizing furnaces. They have installed additional materials handling facilities to help overcome the problem, but, as it originates in the mine, there is no real solution available within the framework of the existing plants.

Sophisticated grading-mining sequence procedures based upon 11,250 ton units (50 x 50 x 45 ft.) are unable to satisfactorily blend the ore. The principal reason is that the metallurgical variation exists on a scale smaller than is measured, and that it is partly related to the structure of the deposit. The structural geometry is variable, however, and is usually different from the geometry of mining block units, thus leading to incorrect estimates. Sophisticated statistical techniques involving trend (directional) factor analyses have so far failed to satisfactorily relate magnetite content to any measurable feature or even describe the character of the body as accurately as would be expected from their closely spaced sample data.

Another problem has arisen because they are now processing significant amounts of ore taken from the Carol East deposit whereas the plant was designed for Smallwood Mine ore. Carol East ore is appreciably harder, with the result that milling rates are reduced.

WABUSH DEVELOPMENT

The nature of the Wabush deposit presented a situation to Pickands Mather that was somewhat different than faced by I. O. C. The extensive cover of thin overburden inhibited geologic investigations and the leached and oxidized nature of the ore hindered diamond drilling. For these reasons, and probably others related to company policy, Pickands Mather emphasized long term pilot plant investigations supplemented by a drilling program sufficient only to demonstrate reserves in a bulk sense.

Their drilling program consisted of a combination of diamond drill holes (poor recovery), and short down the hole percussion-air holes (complete recovery but no core). The pattern was one hole at each corner of a 1000 foot square, plus one hole in the center of the square. Their geologic information is severely limited and they depend largely upon blast hole sample information for grade control purposes. Magnetite is not a problem because so little exists, but manganese distribution and zones of highly oxidized, poor recovery, material do present operation problems.

They built a large pilot plant rated at about 600 tons per day; it contained full scale equipment. They investigated many different types of processing and materials handling equipment. Plant feed was acquired from numerous pits located in various parts of the Wabush deposit. Investigations continued until they had collected sufficient data to insure the proper operation of a sophisticated metallurgical process capable of producing high iron - low silica concentrates in order to compensate for the nearly 2% manganese in the ore that largely remains in the concentrate. They produced over 200,000 tons of concentrate from the pilot plant. This was sold and helped pay for the pilot plant costs.

Some operational performance figures are available which provide measures of general performance. These measures are summarized in the following section as they provide an indication of the performance that could be expected of the Julian operation. Because all deposits in the Wabush Lake district are heterogeneous by nature, average figures are meaningless unless the variation from the average is also given.

The average grade of the Wabush deposit is reported to be 36.48% iron from their 30 year estimate, (April 1966 tax submission). They currently take about 75% of their ore from the west pit, and 25% from the east pit. It is the intention to blend the ore in their storage facilities to make a feed averaging 38% iron to yield a 40% weight recovery, (Skillings, Sept. 23, 1967).

The figures given in the tax submission for the 17-month period, January 1965 to May 1966, indicate that the crude has averaged 35.92 $\pm$ 1.535% iron. The monthly variations, expressed in percent of the 35.92

average, are:

Average variation from average	4.27%
Maximum variation from average	7.29%
Maximum month-to-month variation	12.72%
Average month-to-month variation	5.02%

These are large variations, especially for such large sized units as monthly tonnages.

Mill product performance figures for the 6 month period January-June 1967, are as follows:

	Target	Actual, with Monthly Variation
Concentrates		
% Fe	66.10	65.85 ± .22 (variation .33%)
% SiO_2	2.40	2.27 ± .046 (variation 2.03%)
% Mn	1.60	1.95 ± .21 (variation 10.77%)
Pellets		
% Fe	65.80	65.66 ± .11 (variation .17%)
% SiO_2	2.90	2.92 ± .09 (variation 3.08%)
% Mn	1.60	1.81 ± .12 (variation 6.63%)

The figures are based upon a production of about 400,000 tons of pellets per month, or about 1 million tons of ore. They show that the grade of the ore was lower than expected for seventeen months. Also that a higher than anticipated manganese content has kept the grade of the products slightly below target grade for six months in 1967 in spite of a lower than target silica content. Performance variations range up to nearly 14%, and even in the pellet operation at the end of the process, variations range up to 6.6% average and reach 10-15% in a month-to-month comparison.

Weekly variations for the three months (13 weeks) period

June 29 - September 27, 1967, are shown below. They are presented only for the crude and concentration steps through the spirals, as these steps are comparable with the Julian operation. Variations are shown in "%" of the base average.

Weekly Variations - Wabush - Three Month Period

	Tons Milled	(--------spirals	--------	--------	--------	--------)
	250,000 Ton Target	Crude Iron	Weight Rec.	Wt. R/ Iron Ratio	Conc. Iron	Conc. Mn
Base Average	263,368	35.327	39.52	1.115	63.71	1.55
Ave. Var'n	±17.46%	±3.02%	±4.89%	±3.26%	± .76%	±4.77%
Max. Var'n	63.4%	5.94%	11.84%	5.92%	1.98%	9.03
Max. Wk-Wk. Var.	69.7%	9.28%	16.45%	6.28%*	1.67%	13.55%
Av. Wk-Wk. Var.	17.5%	3.77%	6.3%	2.82%*	.65%	5.16%
Time Beyond Av. Var.	31%	54%	38%	31%	38%	46%
Time Wk-Wk Var. > Av. Wk-Wk. Var.	25%	38%	38%	50%	42%	42%
Time Wk-Wk Var. > Av. Var.	25%	54%	38%	42%	42%	42%

* excludes one week of unspecified plant trouble.

These variations in weekly plant behavior; of up to 16.5% in week to week weight recovery, and operating beyond average variation from 25 to 50% of the time; occur AFTER the crushed ore has been blended by mixing 25% new feed with 75% recirculating load, and AFTER the mixing inherent in normally random truck delivery of ore from about 5 or 6 operating shovels on three or four of the five benches available in two different pits. When this scale of variation appears on a weekly 263,000 ton scale, after blending, and after operation of their grade control system, one wonders what the variations in the deposit itself are?

The figures available provide measurements of heterogenity only at the weekly scale of about 263,000 tons. At a factor of 11 cubic feet per ton, this represents a bench length of about 900 feet of their 40 x 80 lifts, or roughly about 130 feet from each of six shovels.

If all six shovels were excavating essentially identical material one week and different material the following week, resulting in a week to week variation; then the scale of heterogenity would appear to be about 130 feet. To use the 16.5% maximum week to week weight recovery variation as a hypothetical example, the six 130 foot units of ore may have produced material that averaged 8% low weight recovery one week, and the next week six different ore units produced ore that averaged $8\frac{1}{2}$% high recovery. Under normal circumstances, one would expect that about half of the shovels were in normal (zero variation) ore; then the other half of the shovels were producing 16% high recovery ore one week (to blend to 8% high), and they were in 17% low recovery ore the next week, ($8\frac{1}{2}$% low for the week). This situation would result in a change from one week to another of $16\frac{1}{2}$% variation, and it was derived from the fact that the difference in weight recovery between six of the twelve 130 foot mined units was 33 percent of the average weight recovery.

The example above is extreme, but the data do indicate that weight recovery varies through a 10% average variation range for about 60% of the operating time, and is in the 10-33% variation range for about 40% of the time. Most of this variation must originate in the deposit itself and on such a large scale that even with their blending facilities and procedures Wabush is unable to remove these variations in production units measurable in the 200,000 plus ton range. These variations have to be accommodated in the mill by adjusting the flow rates of the material handling and processing equipment, BUT this is just the sort of thing to be avoided as much as possible for a smooth and efficiently operating mill.

THE JULIAN DEVELOPMENT PROBLEM

Metallurgical heterogeneity of an unchangeable geologic origin has been a constant and serious operating problem at the Carol, Wabush and Jeannine plants. Interdependent operating facilities built to handle metallurgical averages cannot operate properly when the averages are made meaningless because of the large variations in the performance characteristics for the materials processed. The variations are known to exceed 30% over a period of a week, and undoubtedly are much larger for shorter periods.

The opportunity exists in the development of the Julian deposit to benefit from the experience of the Carol and Wabush plants and to construct the best plant in the district. The development offers a challenge to metallurgical designers to provide operational control systems that will adequately insure steady state plant operations while processing large tonnages of materials which are characterized by large scale metallurgical variability.

The problems facing the Julian development are, to a degree, a combination of some of the factors which influenced the type of development work undertaken at Carol and Wabush. The fundamental objective at Julian is to prove the existence of a large ore reserve and to quantitatively determine the metallurgical characteristics of this reserve. As the most accessible reserve at Julian exists at depth, deep drilling is a necessity and, although Julian ore is similar to the Wabush ore, direct comparative metallurgical assumptions are not yet justified; pilot plant investigations are therefore needed for plant design requirements.

These objectives can be reached through a development program designed to determine the relationships between the geology and the metallurgy of the deposit. The geology can be investigated only by drilling. The amount of sample produced will be incomplete and inadequate for metallurgical purposes, however, such tests as can be made will provide a useful measure of the geologic-metallurgical relationships in a qualitative sense. The range of metallurgical behavior can be determined by pilot plant investigations on bulk material representing all types of material in the deposit. A model of bulk geologic-metallurgical relationships can then be formulated.

This will suggest a flow sheet and equipment set up whose ability to handle the heterogeneous ore can be tested and refined while operating on a large bulk sample which is as representative of the deposit as it is practical to obtain. The expected pilot plant confirmation of the geologic-metallurgical model should provide sufficient information and confidence in the deposit to proceed with full scale plant design. Appropriate corrections to the drill hole data should be able to provide a general picture of the distribution of metallurgical variability that will be reasonably useful for long term mine development planning, but most short term grade control data will have to be acquired from blast hole samples.

DEVELOPMENT PROPOSALS

The following proposals are offered as suggestions worthy of serious consideration as Julian development work projects. They should provide the information about the deposit needed to proceed with final development design and construction programs. The enclosed illustrations portray the nature of the proposals.

1. Stripping: It is felt that the deposit should be immediately stripped of its overburden down to at least elevation 1800. Mechanical removal is probably the best procedure so that the material can be used for road and dike construction purposes on both sides of the deposit in the east and/or west extensions. Drilling of these extensions should be

done first so that the dikes can be placed in the proper place.

The trench stripping project of 1962 showed the nature of the geologic variability of the iron formation. Once the deposit is stripped, a fine detail geologic map of the deposit can be made. This would provide a sound two dimensional basis for the geologic investigations at depth as well as provide accurate evidence of the surficial configurations of the deposit for mining operations. Assuming that the present geologic map is reasonably correct, the post stripping geologic map might look about as shown, but with much more detail and with direct measurements of the scale of geologic variations.

This stripping has to be accomplished sometime; it would be best to do it first in order to permit other projects to be started and the earlier the better so as to permit the rain to wash the exposures clean. It is estimated that about one half million cubic yards of overburden needs to be removed from the area shown, assuming an average depth of $1\frac{1}{2}$ feet of material removed. The overburden could be monitered but the problem would arise of keeping the material from depositing on the extensions of the deposit where it would only have to be moved again.

2. Drill Holes: The deposit must be drilled with a hole spacing sufficient to reasonably demonstrate its internal geology and in a large enough volume that reserves in the order of about 400 million tons can be considered as proven with a comfortable margin of additional indicated reserves.

Holes 500 feet apart along 1000 foot grid lines is the minimum spacing sufficient to satisfy the requirements if the deposit has been stripped, if not, then many more holes would be required to provide a reliable three dimensional geologic model.

Most of the holes should be drilled to the bottom of the deposit or at least near the arbitarily selected 1200 foot elevation reserve cut-off. Twenty-nine holes, totalling about 15,000 feet and distributed between 7000 E and 13,000 E as shown, should provide much of the information required. A few additional holes might be needed for local confirmation of interpretation, and probably up to a dozen holes will be needed in the lakeward extensions.

It is realized that the iron formation is most difficult to drill, that it will be expensive and slow, and that core recovery will be at best only fair in the leached material. Large core sizes, mud drilling and wire line techniques will have to be used in order to provide the most meaningful results. There is no other way of directly demonstrating bulk, determining the geology, and providing an indication of metallurgical characteristics.

A gravity survey could demonstrate bulk, provide useful information for planning the drilling program, and for geological interpretation. It is suggested that the gravity survey be done early; final interpretation could be deferred until the drill program has been completed.

3. <u>Surface Samples:</u> A project of obtaining a metallurgical

map of the deposit should be started after stripping. The purpose would be to determine the values of the metallurgical parameters across the deposit and relate these to the geology. The samples should be small bulk samples of a few tons each; they could be crushed in the pilot plant and appropriate test work conducted on a representative fraction to provide measures of grade, grindability, weight recovery, etc

The samples would be obtained from small pits located every 100 feet along lines 250 feet apart across the stripped portion of the deposit. It is estimated that about 320 samples should be sufficient to permit reasonably reliable maps of grade, recovery, etc. to be made, but in any case the project should be continued until the pit density is sufficient to provide meaningful results. A hypothetical recovery map is shown in which the recovery variation distribution is closely related to the geology. From such maps, average values, variations, etc. can be calculated for any selected volume of ore for design and operational purposes.

The data will of course be only representative, for it will be based upon sample areas of about 1/10th of one percent of the area of influence of each sample. The metallurgical distribution pattern should be reasonably correct, however, and the map values could be corrected on the basis of operating experience as needed. Map values could also be projected geologically downwards as mining progresses, and with the revisions dictated by experience they would be useful for planning mining sequences.

4. Bulk Samples: Sites for the procurement of large bulk samples for pilot plant runs can be intelligently selected with the information available from the surface sample project. It is suggested that each pit be chosen to supply ores which are metallurgically different so as to provide a separate determination of the operational behavior of each type of material present. The idea is to determine the range of metallurgical variation; there need be no attempt to balance these samples, likely several hundred tons each, to represent the deposit's average. Possible bulk sample locations are shown on the metallurgical map where it will be noted that even twenty pits are obviously insufficient to provide samples representative of the deposit as a whole, even with the aid of the metallurgical map.

A model estimate of bulk metallurgical behavior can be made from this determination of metallurgical variation when considered in terms of the metallurgical sample snaps. Pilot plant facilities could be set up for a large tonnage test which would be expected to confirm the model and afford ample opportunity for refinements and a general test of the plant's ability to cope with sudden metallurgical variations.

5. Adit: It is proposed that an adit be driven through the deposit for two important reasons: (1) to provide the bulk material for the confirmatory pilot plant run; and (2) to drain the water out of the deposit.

All metallurgical sample results previous to this were based upon surface samples, and though it is unlikely, it is also possible that ore at depth may be significantly different from surficial ore material. Regardless of whether this is the situation or not, the pilot plant run should treat, in sequential order so as to test the plant's ability to handle sudden variations, all material encountered from one side of the deposit to the other in order to be truly representative. A continuous cross deposit sample, either at surface or underground, is needed for the pilot plant run.

It is suggested that the adit be driven from a point about 300 feet west of the camp towards the northwest, and passing through Hole 2, until the northwest quartzite footwall is encountered. The length of the adit would be approximately the same regardless of what its starting elevation was in the range of elevation 1750 to 1825; namely about 2600 feet long. As an adit as low as possible will drain the most water, it is suggested that the adit be driven at elevation 1750 from an open cut in the overburden near the road. This adit would likely encounter about 3-400 feet of quartzite, then about 2200 feet of iron formation.

A 9 x 7 foot adit should yield about 53 tons of material per ten feet of length, assuming 12 cubic feet per ton. This would produce a minimum of 12,000 tons of ore material truly representative of the deposit, with the exception that the broken ore size is likely to be smaller than ore broken from open pit faces. Crushing requirements can be based upon the bulk surface sample pits.

The adit should perform the important function of draining water from the deposit in addition to providing material for the pilot plant run. One might consider this as unimportant at first thought, but preliminary calculations indicate otherwise. The deposit is known to be porous and permeable; the degree is not known but is is reasonable to assume that the rock contains at least 15% void space, or about 2 cubic feet per ton. This space, when filled with water, means about 120 pounds of water per ton or ore, or about 5% by weight. If about 3/4 of this water drains away, then about 4% of the net weight does not have to be handled.

If the drainage cone has a slope of about 7 to 1, and is an average of 100 feet deep across the deposit centered over the adit, this involves in excess of 13 million tons of wet ore, 4% of which is approximately 525,000 tons of water. The cost of mining this weight, calculated at the estimated mining cost of 42 cents per ton, amounts to approximately $220,000. This is the same cost as driving an adit 2600 feet at $85.00 per foot, thus any increase in the water content or decrease in the adit costs should result in a net dollar saving, and in any case, the pilot plant feed material has been provided free. If the adit is not driven, perhaps up to $100,000 might be spent acquiring the bulk sample from a surface trench and the $220,000 would only be spent in the next few years needlessly hauling water.

The existence of an elevated water table can easily be confirmed during the drilling program. A check on the behavior of the water table upon draining into the adit will provide valuable information regarding the hydraulic nature of the deposit for consideration of the lakeward extensions situation.

6. Mining Scheme: The selection of bench elevations and general mining plan layout will have to be determined after the geologic and metallurgical investigations are completed. The suggested mining plan enclosed indicates 50 foot benches at elevations 1900, 1950, 1800, and 1750, with suggested roadways at 5% grade. The 100 foot wide units trending northwest are intended to dramatize the fact that the faces should trend northwestward across the geology-metallurgy of the deposit so as to reduce variability. Benches trending parallel with the geology are part of the problems at Wabush and Carol.

Consideration of this scheme in terms of 15 million ton one year ore supply units, indicates that the first year's production would come 45% from all of the 1950 bench and 55% from the 1850 bench; year 2 - 65% from 1850, 35% from 1800; year 3 - entirely from 1800; year 4 35% from 1855, 65% from 1750; year 5 - entirely from the 1750 bench, assuming that all yearly operations were distributed horizontally.

This analysis indicates that the stripping program will have to be resumed at least in the third year in order to expose the ends of the

1750 bench and that waste rock in the south footwall will be encountered in the second year.

DEVELOPMENT PROGRAM

The proposals just described are intended to provide the means of gathering most of the data about the deposit that is needed to begin plant design. The concept involves three procedures.

1. Measurement of the geology of the deposit to the extent that the internal distribution of the various major scaled geologic units can be reasonably predicted in a volume sufficient to prove a 30-year reserve.
2. Measurement of the metallurgical parameters and their variations, and the development of a metallurgical model of the deposit based upon the indicated relationships between the geology and metallurgy.
3. Confirmation and refinement of the model by the continued treatment of a bulk sample as representative of the deposit as it is possible to obtain.

The first two procedures, proposals 2-4, involve samples of the deposit in the order of one per 1000 at the best. It is impossible to estimate beforehand how well such sample data will represent the deposit.

The third procedure, proposal 5, and part of 4, if desired, involves actual pilot plant operations on a representative bulk sample as a test of the metallurgical model and of the plant's ability to cope with rapid metallurgical variations. The plant should be operated until metallurgical techniques are perfected.

The proposals mentioned are in many respects similar to the development work projects undertaken by I. O. C. for the Carol project This project was quite successful and it operated smoothly on the ore and the purposes for which it was designed. Wabush, on the other hand, currently has and probably will continue to have problems maintaining production standards based upon the original estimates. The problem arises not from the plant's inability to handle its feed properly, but rather from an inaccurate estimation of the metallurgical character of the deposit in the first place due to inadequate geologic and metallurgical investigations of the deposit.

It is strongly felt that each proposal is necessary for a proper investigation of the Julian deposit. The drill program could be accomplished more or less independently of the others, but it should be partly completed before selection of the adit location. The surface sample project could be started shortly after commencement of the stripping. Full use of the project will have to depend upon the surface geologic mapping, which will depend upon good exposures. Perhaps the hill could be monitored after mechanical stripping if time becomes important.

It is suggested that the lake drilling and associated investigations be done first in the winter months. If the stripping is begun as soon as possible in the spring, it should be possible to complete the surface sample projects by winter. The adit could then be driven during the winter or following spring. Total development time following this outline would be about a year to eighteen months.

CONCLUSIONS

Operating experience has conclusively shown that the deposits in the Wabush Lake district are geologically and metallurgically heterogeneous on a large scale. This gives rise to in-plant non-steady state conditions and serious operational difficulties resulting from the plant's inability to cope with large metallurgical variations. The proposals outlined should provide the means of gathering information about the Julian deposit sufficient to lead to a reasonably reliable estimate of the deposit's metallurgical characteristics.

But regardless of how much information is gathered, and how carefully it is evaluated, it will still not provide a truly accurate description of the small scale metallurgy of the deposit. The fundamental reason is that the geologic-metallurgical variation in the deposit is going to be so large, and present on such variable scales, that the metallurgical distribution cannot be accurately described even by programs involving many more times the number of samples and drill holes herein suggested. The program proposed can estimate averages, variations from the average, etc., and generally indicate the ball park in which the plant will be operating, but it will not be possible to accurately predict, even after operating experience is gained, exactly what type of material will be fed to the plant on a day to day basis.

For these reasons, the plant facilities must be flexible; there should be several methods of short and even long term blending capable of adequately reducing feed variations of say up to 30% down to tolerable levels for steady state operations from the grinding mills on. Several blending systems need not be installed immediately, but at lease space must be provided for extra cross feed and dynamic storage of materials in case the initial blending facilities are found to be inadequate.

If the challenge of a steady state plant operating on variable feed materials is adequately met, then the opportunity will exist for in-plant refinement of operating techniques, such that it might be possible to consistently produce 65% iron pellets at reasonable recovery levels from spiral concentrates alone. If not, then secondary treatment processes will be needed, as they are at Wabush where recent performance figures show that the spiral concentrates have averaged only 63.7% iron and vary as much as 1.25% Fe on a weekly production scale.

Thus the Julian plant, which will be operating on Wabush type ore, has got to perform better than the Wabush plant, but such highly sophisticated performance will be impossible with feed materials which are constantly changing.

At the risk of being repetitious, the writer would like to say that variance will be the root of nearly all evils in the operation of the Julian concentration plant unless adequate provisions are made to significantly reduce the variation.

David M. Knowles
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