An early appraisal of exploration projects

by D. G. MILLENBRUCH*, M.S. (Tenessee) (Visitor)

SYNOPSIS

An account is given of a four-phase system for the appraisal of a mineral project while it is still in the exploration stage, and for continual consideration of a favourable appraisal until the production stage is reached. There are ten stages from the idea of a likely project to the production stage, and all the staff that are eventually to be concerned with the development of the project are involved at an early stage.

SAMEVATTING

Daar word verslag gedoen oor 'n vierfasestelsel vir die evaluering van 'n mineraalprojek terwyl dit nog in die eksplorasiestadium is en vir die voortdurende oorweging van 'n gunstige evaluering totdat die produksiestadium bereik word. Daar is tien stadiums vanaf die idee van 'n moontlike projek tot by die produksiestadium en al die personeellede wat uiteindelik by die ontwikkeling van die projek betrokke sal wees, word in 'n vroeë stadium betrek.

Union Carbide Corporation is actively involved in the exploration and development of mineral resources in the U.S.A., Canada, and Alaska, as well as in seven countries overseas. Our primary areas of interest at this time are uranium, tungsten, vanadium, manganese, and chromium, and we have a fairly aggressive exploration programme with approximately 140 full-time professional geologists and mining engineers actively engaged in exploration and, of course, a number of other people backing them up. The present mining operations involve uranium-operating facilities at Uravan (Colorado), Gas Hills (Wyoming), Palangana (Texas), and Maybell (Colorado); tungsten facilities at Bishop (California), Tempiute (Nevada), and Boca de Loge (Brazil); vanadium facilities at Rifle (Colorado), Hot Springs (Arkansas), and Brits and Bon Accord (South Africa). The Corporation also has chromium facilities in South Africa and asbestos facilities in California. I am relating the position Union Carbide has in the mining and exploration field since we are generally not known as a mining company, and I would like to add some credibility to the procedure of early exploration assessment that we have used successfully.

We, like others in the exploration business, find that exploration costs are skyrocketing, and that the time from exploration to production has become increasingly longer in the light of environmental and regulatory requirements. We are also, of course, faced with the hard fact that the number of deposits left to be discovered are continually diminishing, and our probabilities constantly become poorer. Some estimates show that exploration expenditure in the past ten years has increased tenfold, while the rate of discovery has only doubled.

The chain sequence shown in Fig. 1 helps demonstrate why Union Carbide finds it necessary to use an early exploration-assessment procedure to try and shorten the chain. In Fig. 1 there are ten links that show how we normally progress from a geological idea, concept, or favourable observation in link 1 to link 2, and, if further study of the geology is favourable or if a preliminary field reconnaissance looks promising, to link 3, where we determine whether the favourable land is available and whether there are any insurmountable environmental problems; then to link 4, where the land is acquired, if possible, to link 5, where preliminary exploration occurs and drill targets are selected; to link 6, when drilling occurs; and, if successful, to link 7, which is commercial discovery and definition of an ore-body; to link 8, where the property is developed with mining and processing techniques defined; to link 9, which is financing and construction of production facilities; and, finally, to link 10, which represents production.

That chain of events is very time-consuming and increasingly costly as we move from left to right, requiring a minimum of eight years, and it can take ten to fifteen years to complete the chain. Also, probably less than one idea or concept out of every thousand passes through the whole chain from link 1 to link 10.

A few years ago, in an effort to combat the problems of sorting out those prospects that were no good, to decrease the time required, and to improve the probabilities of success, we formalized a procedure for early appraisal of exploration projects. Our formalized approach, which has four objectives, is as follows.

(1) Recognize, as quickly as possible, whether an exploration project could be viable.
(2) If it appears that the project will never be viable, abandon it and minimize expenditure on the project; and thus concentrate efforts on those projects with the highest probability of success.
(3) If the project appears viable, develop a timely Action Plan to shorten the time from exploration to production; in other words, adopt the adage that time is money.
(4) If the project could be viable at a later date, place it in a minimum holding-cost situation, rather than continuing to sink money into it earlier than required.

The following summarizes the objectives: Give the proper priority to all exploration projects in order to place funds where they will do the most good, as quickly as possible, and with the highest probability of success.

The appraisal system we have been using, and that has proved fairly successful, involves a four-phase procedure of evaluation and development. This procedure must be 'triggered' or initiated by the explorationist. When the exploration geologist believes that

*Union Carbide Corporation, New York, U.S.A.

there is a *chance* that he has found a viable ore-body, a recommendation is made to initiate a Phase I Feasibility Study. Assistance is regularly given to the geologist to help him make that judgment through hypothetical guidelines, which are routinely calculated and placed at the disposal of all exploration personnel. These guidelines cover a broad range of possible ore deposits and mining and processing schemes, and show the types of deposits that would be viable. The guidelines also serve the dual purpose of providing exploration targets to the explorationist.

An example of such a guideline is given graphically in Fig. 2, which shows the effect of ore grade on the economics of a tungsten deposit for two tungsten sales prices. These curves are for a 700 000 ton ore-body that would be mined by underground-mining techniques and milled through a conventional flotation concentrator. We also supply curves for open-pit mining, other levels of

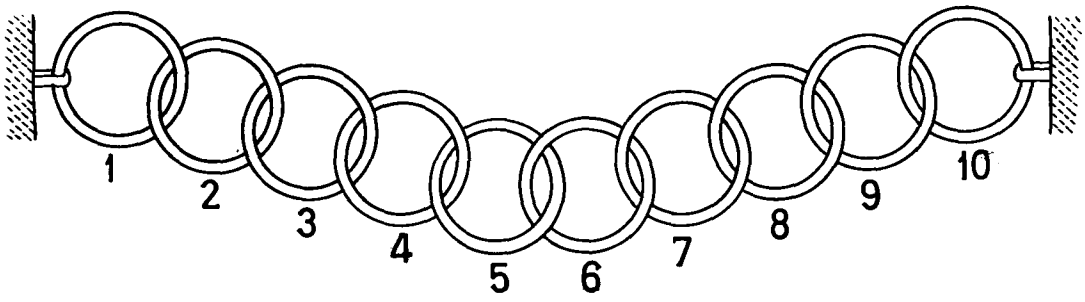

Fig. 1—Chain of events from idea to production

Link 1—Geological idea or concept, or favourable observation from field work
Link 2—From further study, geology appears favourable; preliminary field reconnaissance
Link 3—Favourably located land available; no insurmountable environmental problems
Link 4—Favourable land costs, funds available, and land acquired
Link 5—Preliminary exploration and selection of drilling targets
Link 6—Drilling
Link 7—Commercial discovery, ore-bodies defined
Link 8—Property developed, i.e., mining and processing procedures developed
Link 9—Production facilities financed and built
Link 10—Production

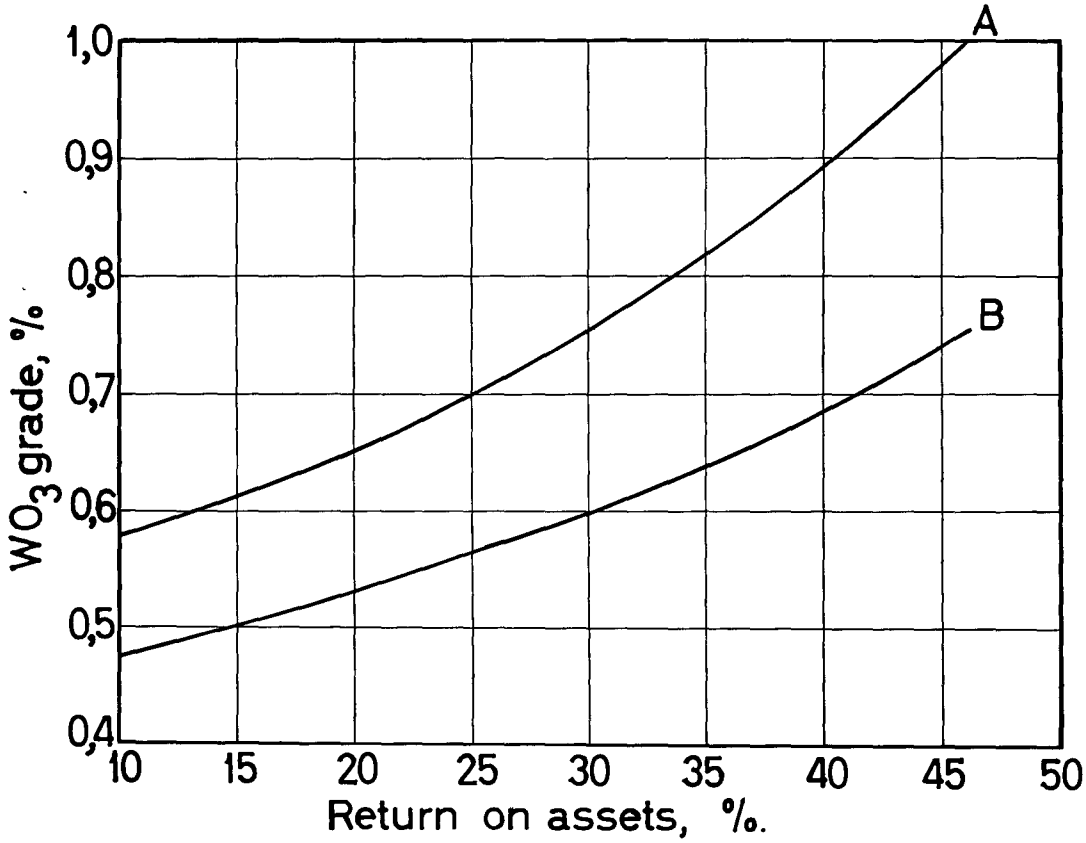

Fig. 2—Effect of grade on the economics of a tungsten deposit (700 000 ton reserve, underground mining, conventional flotation concentrator) A=$13 000 per short ton; B=$17 000 per short ton

ore reserves, and other variables. Our geologists are supplied with a whole suite of these curves to help them keep the desired targets in mind, as well as to help them judge when a find should receive an early assessment. The curves are routinely updated as conditions change.

The objective of a Phase I Feasibility Study, once we embark upon it, is to develop sufficient information to make a preliminary order-of-magnitude evaluation that will indicate whether the prospect under consideration could be an economically viable deposit. The results of the study must be treated cautiously: they are of a *very* preliminary nature, should be used only for planning, and should receive guarded distribution. A certain amount of management education is necessary to ensure that the results are not misused. We do not want management to believe that the economic results are cast in stone, but rather that they are merely 'indicators' in view of the level of knowledge of the prospect at that time. At the time these studies are made, the level of knowledge of the project is limited, and any feasiblity study could be only an order-of-magnitude indication. In fact, some of the information would be of the 'best guess' type of estimate. Be that as it may, the study still serves as a valuable guide.

TABLE I

PHASE 1, STUDY MEMOS FOR A URANIUM PROJECT

Memo	Assign-ment	In co-operation with	Date due
(a) Project description and scope	Smith		9/12/75
(b) Estimated ore reserves (by type, grade, etc.)	Jones	Henrie	11/1/75
(c) Estimated mining plans and costs, including capital	Cohan	Moore	12/1/75
(d) Possible conventional flow-sheet and estimated costs	Wills	Adams	11/1/75
(e) Estimated *in situ* leaching plans and costs	Adams	Spencer	11/1/75
(f) Environmental requirements	Beverly	Wentzel	11/1/75
(g) Availability and cost of resources, i.e., manpower, reagents, power, fuel, etc.	Wentzel	Moore	11/1/75
(h) Operating-cost estimate	Wentzel	Woolery	12/1/75
(i) Capital-cost estimate	Spencer	Wentzel	12/1/75
(j) Feasibility study	Wentzel	Smith	1/1/76
(k) Review meeting	All		2/1/76

The Phase I Study is started by a meeting of key interested parties, at which an Action Plan, including a budget and timetable, is prepared. The information to be gathered is presented in Study Memos that are assigned to individuals who are the best qualified in the particular area of interest, and are distributed to all interested and involved people. The types of subjects and memos normally prepared are as follows:

(a) Project description and scope
(b) Expected ore-deposit nature and environment, i.e. depth, potential size, potential grade, water conditions, ground conditions, etc.
(c) Land status to include holding and/or projected acquisition costs.
(d) Preliminary assessment of environmental requirements
(e) Possible mining or *in situ* leaching methods and order-of-magnitude costs
(f) Possible flow-sheets, largely based on mineralogy at this stage
(g) Availability of resources, i.e., power, water, manpower, etc.
(h) Possible operating costs
(i) Possible capital requirements
(j) Preliminary economic feasibility study.

All memos are prepared in a standard format, and revisions are issued as new information becomes available. A list of study memos for a typical project is shown in Table I.

The entire Phase I procedure should require only a few weeks or months to complete, and should culminate in a review meeting and, possibly, a Phase II planning meeting.

The recommendations of the preliminary feasibility study would probably be one of four.

(i) Drop the property. Sell or dispose if it is of no interest to Union Carbide.
(ii) Hold the property as a resource with the thought that it could be developed at a later date. In our economic studies we usually make a sensitivity analysis, which might show that the project could be viable under conditions that could occur at some later time.
(iii) Continue exploration in normal fashion; return looks O.K.
(iv) Accelerate efforts on project; return looks very good, or perhaps the time of best-market conditions is in the near-term.

If one of the last two courses of action was recommended, the next stage, or Phase II, would be initiated by again developing an Action Plan, including a budget and timetable. At that stage things get more expensive. The objective of Phase II would be to prepare a feasibility study with a relatively *high* degree of credibility. If the property is not controlled by this time, it should be acquired before proceeding. This phase could take several months, or even years, and would result in information and data presented as 'Feasibility Memos, Phase II'. The memos are similar to those in Phase I, but are more detailed and more accurate, containing the following:

(1) Project description and scope
(2) Ore-deposit definition, geological ore reserves (probably at least indicated), i.e., grade, tonnage, depth,

TABLE II

PARTICIPANTS IN EACH PHASE

	Phase I	Phase II	Phase III	Phase IV
Exploration	×	×	×	
Resources development	×	×	×	×
Research and development	×	×	×	×
Engineering and construction	×	×	×	×
Environmental and safety	×	×	×	×
Production			×	×
Product general manager	×	×	×	×
Appropriate business analyst		×	×	

water condition, preliminary rock mechanics, etc. (all a result of a drilling programme)

(3) Estimated mining costs — now based on some rock mechanics, an estimate of mine dilution, and a reasonably well-defined mining system, i.e., with an accuracy of approximately 25 per cent

(4) *In situ* leaching costs, if applicable, based on knowledge of formation, formation porosity, etc.

(5) Flow-sheet definition based on bench-scale and amenability-type testing, and a better knowledge of the mineralogy, etc.

(6) Preliminary assessment of environmental requirements and associated costs with knowledge of expected effluents and applicable laws, and the time needed for the acquisition of all permits and approvals

(7) Estimated operating costs with an accuracy of approximately 25 per cent

(8) Capital cost based on above flow-sheet with an accuracy of about 25 per cent

(9) Feasibility study.

At this stage, within Union Carbide, the management of the property would probably be transferred from Exploration to Resources Development, which is the group that specializes in development-type activities.

The objective of Phase III would be a completed engineering design package, which we refer to as a Scope Package. The data generated in this phase are of a high degree of credibility, and should result in estimates of capital and operating costs with an accuracy of about 10 per cent. Another way of looking at this phase is that it is aimed at generating information of such a degree of accuracy that the risks are acceptable for committing major amounts of capital to a facility. Again, a project description, scope, and assignments are prepared for this phase that would define all the design memos required to cost and build the facility. The Scope Package could be presented to either an engineering firm or an internal engineering group, and would serve as the design basis for the design and construction of a facility and the purchase of mining and milling equipment. The action in this phase is as follows:

(a) Development drilling and test mining to generate the ore grade, quantity, and cost delivered at the mill

(b) Possibly, field *in situ* testing to generate similar data if that were the extraction method being considered

(c) Laboratory and/or pilot-plant studies to accurately define the recovery and operating costs of the flow-sheet

(d) Testing of engineering equipment, etc., to generate reliable equipment selection and capital costs

(e) Action to ensure the availability of all the other resources required, i.e., manpower, reagents, energy, water, etc.

In most cases, as stated earlier, it is likely that we would proceed to the final step, Phase IV, when we embark on Phase III. Phase III could take from a few months up to a year.

The following action would occur in Phase IV:

(i) Acquisition of funding internally or externally

(ii) Design of the facility

(iii) Continuation of development drilling, and start of decline, stripping, shafts, and any other mining development indicated,

(iv) Construction of the facility.

Within Union Carbide, during or at the end of Phase IV, management of the project would be transferred to the Production Group.

In all phases of the assessment procedure I have described, various groups and/or departments become involved in the project. Table II gives a listing of the groups in Union Carbide that are involved in each phase. I believe this to be an important feature: we have found that, if all the groups that are to be involved eventually in developing an exploration project are involved at an early stage, things go much more smoothly. The appraisal approach I have described has been helpful to Union Carbide. I am sure other companies have other procedures that may work just as well or better, but I wished to share an approach with you that has worked well for us. Not only does formalization of the procedure shorten the time from exploration to production by minimizing faltering around, but it also places priorities where they belong. Also, within a large company such as ours, where a number of people and departments are involved, the procedure serves as an excellent communications tool, keeps top management advised of possible future projects, and helps in long-range planning and in the prediction of capital needs.