THE HYDROLOGICAL ENVIRONMENT AT THE GAYS RIVER MINE

GAYS RIVER, NOVA SCOTIA, CANADA

D. M. McKEE, P. Eng.* and P. J. HANNON, P. Eng.**

*Project Manager, Esso Minerals Canada, P. O. Box 4029,
Terminal "A", Toronto, Ontario, M5W 1K3 (Formerly Mine Manager,
Gays River Mine)

**Manager of Mining Engineering, Nova Scotia Department of Mines
and Energy, P. O. Box 1087, Halifax, Nova Scotia, Canada,
B3J 2X1 (Formerly Mine Superintendent, Gays River Mine)

ABSTRACT

The Gays River zinc-lead deposit is hosted by a carbonate reef
complex and overlain by the evaporites gypsum and anhydrite.
Erosion at the carbonate-evaporite contact took place during the
Lower Cretaceous period. This erosion led to the formation of a
karst topography which was in turn overlain by lacustrian and
fluvial sediments. Soil piping structures in these sediments
have made mining very costly and dewatering uncertain. The
history of the effort to control the water is discussed.

INTRODUCTION

The Gays River Mine is located in the Milford area of Nova
Scotia, approximately 70 km N.E. of Halifax. (Figure 1)

The mineral deposit, a Mississippian Age, carbonate-hosted
zinc-lead body, was discovered in April 1973 during a drill
program carried out jointly by Cuvier Mines Ltd. and Imperial
Oil Limited, with Imperial as operator.

Originally presented at the 1982 Annual Meeting of the Mining
Society of Nova Scotia, in affiliation with the Canadian Institute of
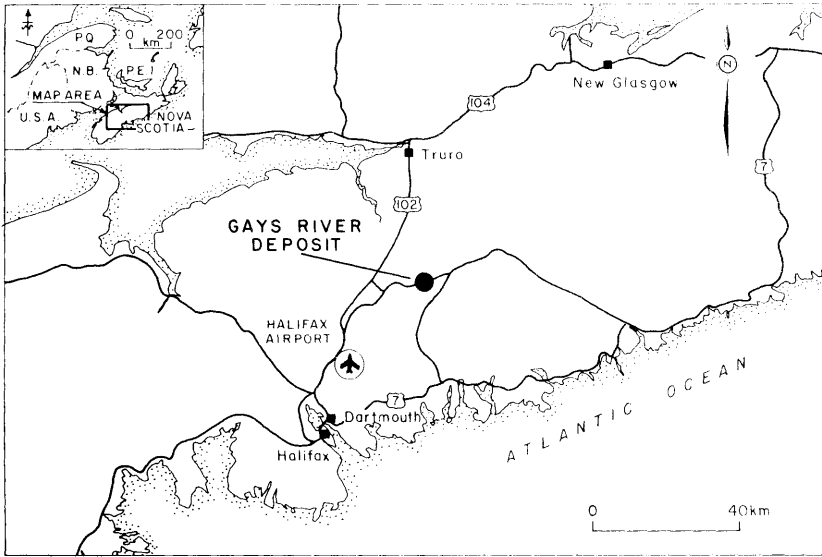Mining and Metallurgy and reprinted with permission.

Figure 1:   Gays River Location Map

SINKHOLES IN
RELATION TO SURFICIAL GEOLOGY

▨ HUMMOCK TERRAIN

○ SURFACE SINKHOLE

2 ● BATHYMETRIC SINKHOLE

HWY 224

GAYS RIVER

TRENCH

DENSE CLAY
GLACIAL TILL
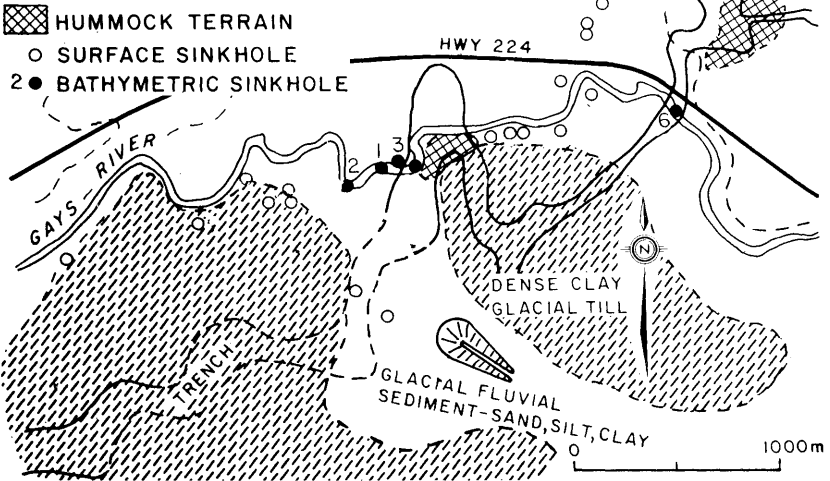
GLACIAL FLUVIAL
SEDIMENT-SAND, SILT, CLAY

1000m
0

Figure 2:   Sinkholes in Relation to Surficial Geology

14

Knowledge of the existence of lead and zinc in this area dates
back to 1824 and possibly to the 1700's (1). The area was
explored sporadically over the years by several companies. In
1972, Cuvier Mines discovered high grade boulders to the south of
the known deposit, staked the area and then optioned it to
Imperial Oil Limited. By late 1974, a total of 460 diamond-drill
holes had been put down outlining an irregular mineralized zone,
approximately 4 km long by 220 m wide, at depths varying between
20 m and 200 m below surface.

Between late 1975 and August 1976, an exploration decline was
driven across the central part of the mineralized zone to verify
mining conditions, the grade and continuity of mineralization,
and provide bulk samples for metallurgical testing.

During the next two years various feasibility studies were
carried out and Imperial Oil Limited acquired 100% interest in
the project and took the decision to bring the property into
production. Recoverable proven plus probable reserves were
estimated to be 4.7 million tonnes at 2.8% lead and 4.2% zinc.

Construction of surface plant and mill processing facilities
commenced in 1978, and the mine was further developed to support
an intended production rate of 1350 tonnes per day. Mill produc-
tion commenced in October 1979, and by mid-summer of 1981 a total
of 554 000 tonnes of ore and 272 000 tonnes of waste had been
mined. Throughout this period, efforts to achieve the full pro-
duction rate, as well as efforts to mine areas of higher grade
mineralization were continually thwarted by the combination of an
extremely complex geological setting and severe hydrological
problems.

Production operations at Gays River Mine were suspended indefi-
nitely on August 15, 1981, as a result of continuing problems
with ore grade continuity and underground water. This paper
discusses the geological and hydrogeological environments with
reference to the mining operations undertaken.

GEOLOGY & GEOHYDROLOGY

The geology of the Gays River deposit and general area has been
reviewed in several previous papers and theses (2, 3, 4, 6, 7, 8,
9, 10, 11, 12, 13). Figure 2 illustrates the sinkholes in
relation to the surficial geology at the mine site.

Stratigraphy

The detailed stratigraphic sequences at the Gays River Mine are
given in Table I. Figure 3 illustrates the hydrogeological units·
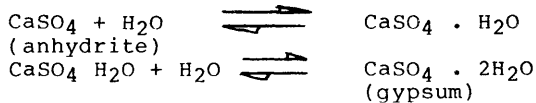and geology at the Gays River Mine.

15

The Goldenville Formation is composed of thickly bedded, highly jointed quartzite (subgreywacke), with minor slate along the bedding planes. The Formation is generally impervious and dry with the exception of rare fracture zones.

Topographically, it has controlled the later units deposited and therefore had both a direct and indirect effect on the ground-water flow system.

The basal unit is composed of angular blocks of the Goldenville Formation bounded by a dolomitic carbonate matrix.

A lower pebble conglomerate unit is noncalcareous suggesting a precarbonate complex regolith or perhaps a beach. The upper part of the unit includes boulders up to 2 m across. These two lithologies are dry except where the rock is highly jointed, and at the carbonate "trench" contact where the original dolomitic limestone has been altered by calcium sulphate rich water to a vuggy black limestone (dedolomitized).

The evaporites, gypsum and anhydrite are impervious but soluble, with gypsum being about 20 times more soluble than the anhydrite under mine and river water conditions. With the addition of water, anhydrite is altered to hemihydrate and then to gypsum.

$$CaSO_4 + H_2O \rightleftharpoons CaSO_4 \cdot H_2O$$
$$\text{(anhydrite)}$$
$$CaSO_4 \, H_2O + H_2O \rightleftharpoons CaSO_4 \cdot 2H_2O$$
$$\text{(gypsum)}$$

The solubility of gypsum in water is somewhat greater than 2000 ppm (14, 15). This solubility is increased in the presence of sodium chloride or magnesium chloride.

The mine water discharge was typically 1250 to 1300 ppm SO_4, while the Gays River SO_4 concentration generally varied between 60 ppm (winters) and 400 ppm (summers).

Trench

Before or during the lower Cretaceous Period, a general upliftin of the area (Figure 4) with respect to sea level subjected the sequence to surface and subsurface erosion with the solutioning of vast quantities of evaporites. The most serious erosion, fro a mining point-of-view, took place in the evaporites at the present or ancient evaporite-carbonate contact. Here, dolomitic

TABLE-I
STRATIGRAPHIC UNITS, GAYS RIVER MINE

| ERA	PERIOD	DIAGRAMATIC COLUMNAR SECTION	LITHOLOGY	HYDROLOGICAL CHARACT
CENOZOIC	QUATERNARY (Pleistocene)	FLOOD PLAIN RIVER / FLUVIAL SEDS / GLACIAL TILL / TILL / BEDROCK	Recent stream sediment. Glacial till cut by outwash channel Till, Bedrock	Glacial fluvial sediments-silt, sand and gravel cutting clay rich glacial till	Glacial fluvial sediment homgenous aquifer Glacial till-soil piping
		There is no record of Tertiary Sediments		
MESOZOIC	CRETACEOUS (Lower)	TRENCH / SINK-HOLES / REEF / EVAPORITES	Trench eroded between carbonate and evaporites	Trench: hard, dense clay, clayey silt, and gravel and gypsite	Trench-soil piping (large capillaries) Cavernous zones
		There is no record of Pennsylvanian, Permian, Triassic, or Jurassic Sedimentation Uplift and Erosion, (Post Lower Mississippian, Pre Middle Cretaceous)		
PALEOZOIC	MISSISSIPPIAN — Gays River Formation	+ ANHYDRITE + CALCARIOUS SILT REEF GYP	Anhydrite with Gypsum & argillaceous limestone/dolomite horizons	Calcium Sulphate Salts	Impervious (but soluble)
	CAMBR-ORDOV. WINDSOR Group	Erosion? ALGAL FACIES SEA LEVEL FORE REEF CORAL	Reef complex micritic, algal, clastic, and coral facies	Dolomitic limestone dedolomitized vuggy carbonate at the trench contact	Fracture porosity
	Meguma Gr. Gold Vl. Frm.	Folding, Faulting, Uplift and Erosion SLATE QUARTZITE (SUB GREYWACKE)	Blocky, massive quartzite to greywacke beds with slate horizons	Quartz sand, minor chloride	Essentially imperous Fracture porosity only

17
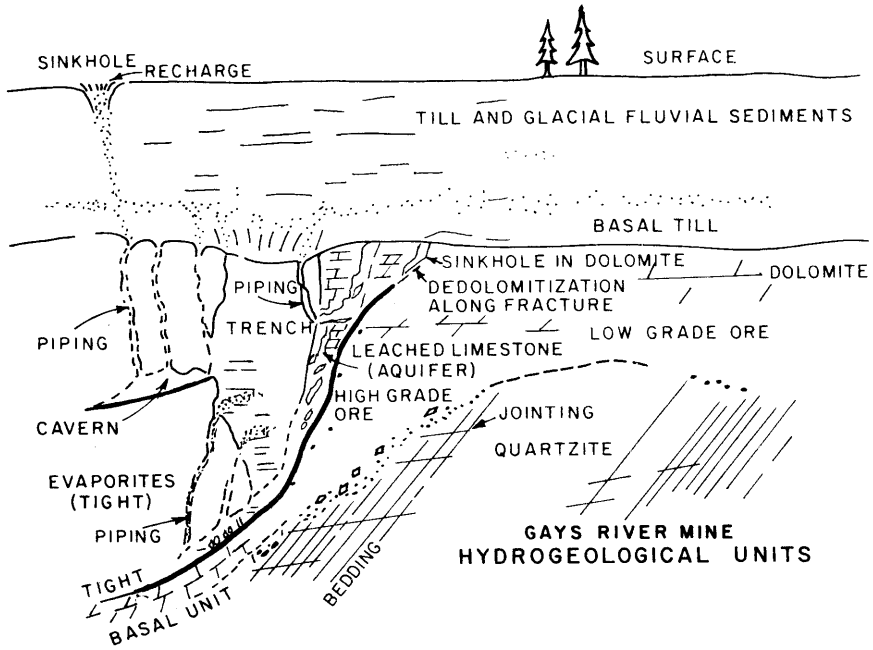
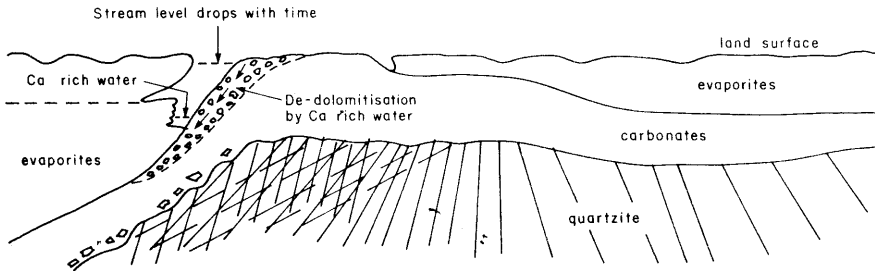Figure 3: Gays River Hydrogeological Units

Figure 4: Reconstructed (Lower Cretaceous) Cross-Section

18

limestone of the reef complex was altered to a vuggy black limestone; the gypsum front was eroded back from the carbonate complex by several metres to 10's of metres; caves were formed in the gypsum and numerous pits and sinkholes formed a karst topography at the surface of the evaporite sequence. The erosion or solution "trench" was then infilled with mud, sand, silty sand, gravel, and gypsite (the insoluble residue from gypsum). Dating of the "trench" infill material was based on the identification of the spore/pollen assemblage and performed by the Esso Minerals Research Laboratories in Calgary (16).

The quantity of groundwater flow through the trench sediments is unknown. Underground the mass of the poorly-sorted sediments appears impervious but significant inflows have occurred through soil pipes near the carbonate contact and at the trench-evaporite contact.

The general bedrock and "trench" are overlain by a thick mantle of clayey-glacial till with some localized glacial-fluvial deposits. The clayey-glacial till ranges from 20 m to 40 m in thickness with more where remnant surface hills occur. The till, in turn, is cut by glacial-fluvial deposits of sand, silty sand, and gravel and in places these sediments may be in contact with the bedrock. The fluvial sediments cut the till in the present Gays River Valley in the mine portal area and the 118-119 mining areas. This unit is believed to have a relatively high permeability.

Present erosional processes are depositing silt and fine sandy silt in the Gays River and its floodplain. This material is relatively impervious, but can easily be breached by soil piping structures.

Mineralization

The lead and zinc mineralization occurs as galena and sphalerite disseminated through the carbonates in the fore-reef talus and reef crest areas, in pore spaces and fracture fillings, as well as in massive veins of reasonable continuity, located at the present carbonate-gypsum or carbonate "trench" contact. The thickness and grade of this type of mineralization is extremely erratic and varies from a few millimetres to over 5 m with sample grades up to 69.5% Pb and 55.5% Zn being observed (Figure 5).

Surface Drainage

The Gays River Mine is located northeast of the confluence of the Gays and South Gays Rivers. The Gays River, which actually flows

over a portion of the orebody, drains an area of about 194 km^2.
The average annual precipitation in the area is 1250 mm per year,
based on data from Halifax International Airport and nearby Upper
Stewiacke. The average flow in the Gays River is 7 m^3/s,
although flow rates in the vicinity of the mine range from a low
of 0.1 m^3/s during dry periods to over 17 m^3/s in flood. Flows
in excess of 11.9 m^3/s spill out over the river floodplain and
this can occur throughout the year.

Prior to mining activities, the groundwater flow system was in
equilibrium, with recharge entering the system at higher ground
and discharging from the overburden, "trench", and bedrock
systems to the Gays River, its tributaries and adjoining bogs and
wetlands.

MINE DEWATERING

Original Concept

Many orebodies have been successfully mined under various bodies
of water, bogs, or wet overburden. In some cases, grout curtains
or freezing techniques may be required to permit the installation
of a concrete-lined accessway before the bedrock or deposit
itself provides a barrier against inflows of water. In other
cases, a cap rock of solid ore may be left in place or even
rendered more impervious by grouting to hold the water out.
Dewatering of the mine can usually be accomplished by conven-
tional pumping with the occasional grouting of inflows of water
from fractures, fault zones or other natural weaknesses in the
rock.

The Gays River deposit is overlain mainly by impervious
overburden, with the river flowing over or alongside a
substantial portion of the deposit. The aerial extent and
complex geological features of the deposit render some of the
usual approaches uneconomical. With approximately 0.9 km^2 of the
mineral deposit surface in contact with overburden and "trench"
material, it was deemed impractical, as well as uneconomical to
attempt to establish a grout curtain over the orebody. Freezing
techniques were also ruled out for the same reasons.

The approach adopted was to dewater the overburden in the
vicinity of the portal by means of surface wells, to establish
initial access to the deposit and then use the rock or a portion
of the deposit as a barrier against water inflows. Initial
criteria for establishing a mineable ore reserve included
maintaining a 6 m "safe back" between any mine opening and the
overburden or "trench" contact, even though this sterilized
considerable mineralization. In addition, 6 m of solid, corable

evaporites, immediately overlying the ore zone, were required for
mineable reserves underlying this zone. It was believed that 6 m
of solid rock would provide a stable pillar and an adequate
barrier to prevent excessive inflows of water. Mine dewatering
could then be achieved by conventional pumping, requiring only
occasional grouting of inflows expected from the intersection of
diamond-drill holes. The initial underground pumping system was
designed for a total mine discharge of 190 l/s. This was based,
in part, on the results of a reconnaissance hydrology study
conducted in 1974, which included installation of a groundwater
observation well network and an initial evaluation of existing
groundwater conditions.

Initial attempts to develop the mine without advance dewatering
were soon impeded by unpredictably high inflows of water.
Development cycles were disrupted with water inflows following
blasting operations, which resulted in flooded headings being
alternately pumped down -- mucked -- pumped down, and so on until
the round was mucked out enough to permit construction work to
control the inflow. In addition, because of the proximity to
overburden, the Karst features and the "trench", most water
inflows contained solids (clay and sand) which buried pumps, cut
pump impellers and mechanically enlarged the inflow channel, thus
compounding the problem. The inflow of water and solids to the
mine eventually led to surface collapse and the formation of
sinkholes. Inflows containing solids therefore had to be sealed
quickly to prevent buried pumps, mechanical enlargement of the
inflow channel and excessive sinkhole development. This was
usually accomplished by a combination of concrete bulkheads, with
or without grouting, and by filling and landscaping sinkholes and
the general surface area to help reduce inflow and increase
runoff.

Testhole procedures were designed to maintain a 6 m "safe pillar"
and verify that the rock ahead contained no major cavities or
heavily-fractured water-bearing zones. Because of the undulating
and sinuous nature of the ore topography, long testholes were
impractical and it was necessary to drill two and sometimes three
10 m testholes ahead of each round and towards the overburden or
"trench" contact. Despite these and other attempts to locate
flow channels and water-filled cavities by the use of electronic
means (side scanning radar), the unexpected interceptions of
water continued to disrupt development schedules.

Dewatering Drains

The next stage was an attempt to dewater the overburden by
drilling drains from underground towards the overburden as mine
development advanced. This approach appeared to have reasonable

21

success in the reef crest development and down to the No. 5 sump
elevation. However, as development proceeded underneath the
"trench" and evaporites, it was apparent that while the water
table was definitely lowered in some areas, other areas had
little drawdown with a static head at, or close to, surface.
This placed some underground headings under a pressure of 0.7 to
0.8 MPa, making any inflows extremely difficult to seal off.

Depressurization

In late 1979, unexpected water interceptions and high water
pressures in some mining areas appeared to be the major obstacles
preventing the realization of tonnage and grade targets. An
investigation was initiated to determine means of depressurizing
the deeper workings without dewatering the entire orebody (17).
Unfortunately, systematic records of the response of the
groundwater system were not maintained during the development of
the mine from 1976 to 1979, thus creating a serious gap in the
hydrologic record. In 1980, additional monitoring points were
established and maintained in an attempt to define the
groundwater regime and determine the movement of groundwater
through the various structures. Preliminary studies of possible
river diversions and channel improvement were also conducted and
later abandoned as being of little benefit because of the
relationship of water sources and general area geology. The
final report (17) concluded that three relatively independent
groundwater systems affected further development of the mine:

1. Unconsolidated materials which in-fill portions of the
    "trench" consist of fluvial sands and gravels with high
    permeabilities, which are capable of transporting large
    volumes of water into the deeper portions of the mine.

2. The groundwater system associated with the Gays River and
    floodplain is, for a large part, "perched" on top of the
    glacial till which itself has a relatively low permeability.
    As a result of observed changes in groundwater levels with
    development of the mine, it was inferred that the "trench"
    was only weakly interconnected with these near surface
    groundwater systems.

3. The flow of water through glacial outwash sands and into the
    mine workings is controlled largely by the surface topography
    and underlying bedrock surface.

Depressurization Wells

A depressurization scheme was subsequently devised (18) which
involved the drilling of dewatering wells from surface to

intersect the sand-filled cavity sections in the gypsum front
near the "trench". A system of seven observation and three
production wells were laid out and designed to intersect
cavernous zones in the deeper sections of the "trench", in
valleys between the two principal mineralized areas located in
the central zone of the mine. This program was only partly
successful since problems associated with drilling through
approximately 30 m of overburden and then into a karsted gypsum
bedrock, containing large cavernous zones, resulted in the
frequent loss of circulating medium and the necessity to install
several stages of casing with subsequent reductions in hole
diameter. It was necessary to start a hole at 50 or 60 cm in
diameter in order to obtain a minimum 20 or 25 cm cased/screened
well. Furthermore, the "trench" and associated geology was not
precisely defined by diamond drilling and interpolation between
holes proved less than satisfactory. The end result was that,
while five observation wells were installed with reasonable
success, only one of the three production wells encountered
water. The other two wells failed to intersect the aquifer
structure and attempts to fracture them by blasting were
unsuccessful. Hydraulic fracturing was considered but the idea
abandoned because of the shallow depths and the possibility of
fracturing to the river or river floodplain. The one successful
well (DW#3) was pumped at 60 l/s beginning in March 1980 and
obtained significant drawdown over a considerable area with some
response noted up to 1000 m distance.

Depressurization Drains

As a result of the drilling difficulties, high cost and
uncertainty of intersecting the desired aquifer structure with
surface wells, the idea of underground drains was resurrected.
As mentioned previously, this method was used during the initial
decline work and later mine development when pressures were more
moderate. The technique was improved to permit installation of
valved drains in areas of high pressure (+ 0.7 MPa) and flows up
to + 65 l/s (Figure 6). The technique involves drilling a 15 cm
hole, 1.5 m into the solid quartzite using a longhole machine. A
flanged 12.7 cm collared pipe is then inserted into the hole,
rockbolted and "preco-plugged" in place. A 50 mm diameter hole
is then drilled inside the flanged insert to the carbonate con-
tact, reamed to 100 mm diameter and finally redrilled at 50 mm
diameter through the carbonates to the gypsum contact or
"trench". A flanged valve is then attached to the insert by one
bolt, the valve opened and rotated through the water stream into
position and firmly bolted in place. The valve permits closing
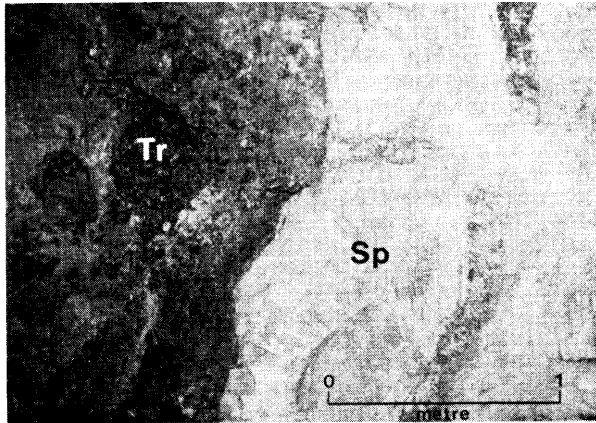the drain in event of power or pump failure.

Figure 5:   Photo of Massive Sphalerite – Trench Contact
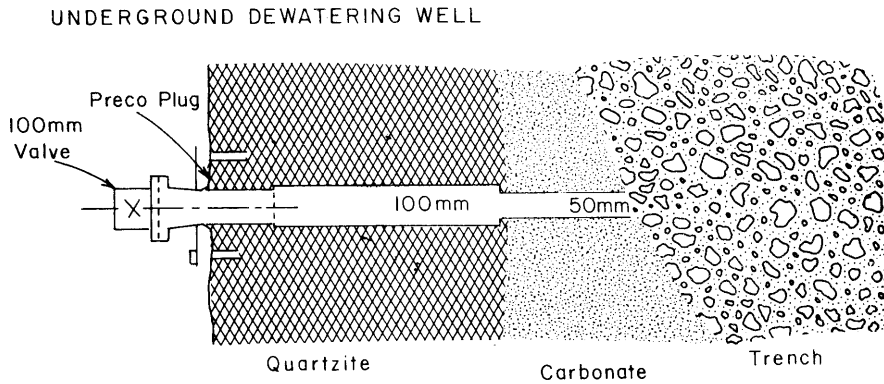   Sp-Sphalerite, Tr-Collapse Breccia in Trench

UNDERGROUND DEWATERING WELL

Figure 6:   Underground Dewatering Well Set-up

24

Sinkholes

Through the combined efforts of pumping from DW#3 and the under-
ground drains, the water table dropped markedly in the vicinity
of the Central Zone. One phenomenon noticed was the gradual
creation of sinkholes on surface. These varied from 2 m to 5 m
in diameter and from 2 m to 4 m in depth, with most being located
in the glacial-fluvial sediments overlying the 119 mining zone.
No noticeable solids were being drawn into the mine at this time,
so it was believed that the sinkholes were forming by the
collapse of material into cavities once the water was withdrawn
from voids created as the gypsum was taken into solution as well
as from the silt fraction being stoped from water-bearing cracks
through the nearly impervious trench material. In order to limit
direct recharge through the sinkholes, they were filled with
waste rock and capped with clay (Figure 7). Later, the entire
area was cleared of trees, graded and landscaped to lead water
away and permit rapid runoff.

Suspension of Production Operations

The water table over the 119 area has been lowered and develop-
ment in 118 was proceeding towards the construction of a new
sump. It was therefore decided to resume mine development in 119
to verify ore grade and continuity under the evaporites.
Although the area was still under some pressure, this zone was
considered to have 6 m or more of solid gypsum or anhydrite rock
overlying the ore zone. It was therefore deemed safe to advance,
with caution, providing testholes were drilled above and ahead of
each round and the grouting of minor inflows undertaken
immediately. However, the testhole procedure failed to detect
the presence of major water-bearing sheet-like channelways at the
gypsum-carbonate contact in the 119 E, F, and G headings, which
were subsequently halted upon encountering inflows of up to
100 l/s following blasting. The inflows were quite dirty with
the 119 G inflow of 100 l/s conducting solids into the mine at a
rate of 4 to 5 tonnes per hour. The inflows were eventually con-
trolled with considerable difficulty by pouring large reinforced
concrete bulkheads to seal off the drift face. It was now
obvious that mine development could not proceed under even
supposedly solid gypsum until the area had been completely
depressurized. Because the bulk of the high grade mineralization
lay under cavernous gypsum or adjacent to the "trench", a
decision was taken to suspend production operations and determine
the feasibility of controlling the water, as well as changing the
mining method to recover a higher grade of mineralization.
Figure 8 illustrates the development of sinkholes as a result of
the mining operation.

25

Figure 7:   Photo of Sinkhole in Glacial Fluvial Sands Over the
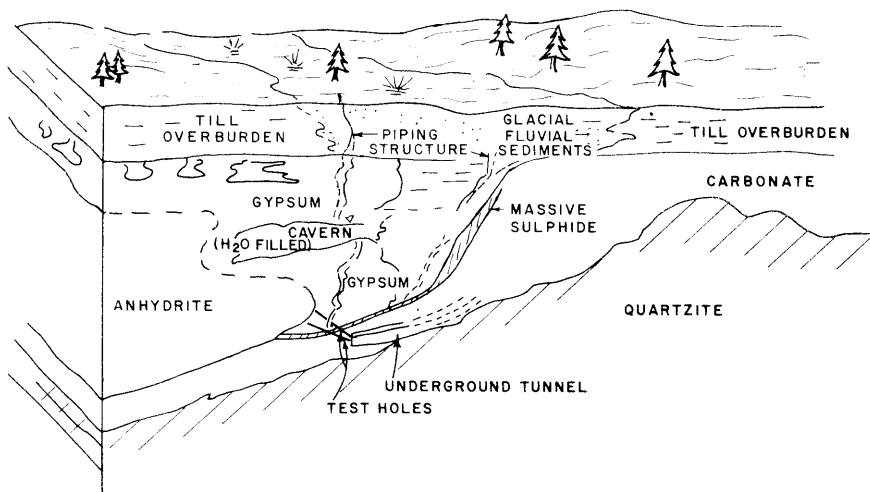   119 Area

Figure 8 (a):   The underground heading is advancing in ore,
                testholing along the way. The testholes miss the
                piping structure.
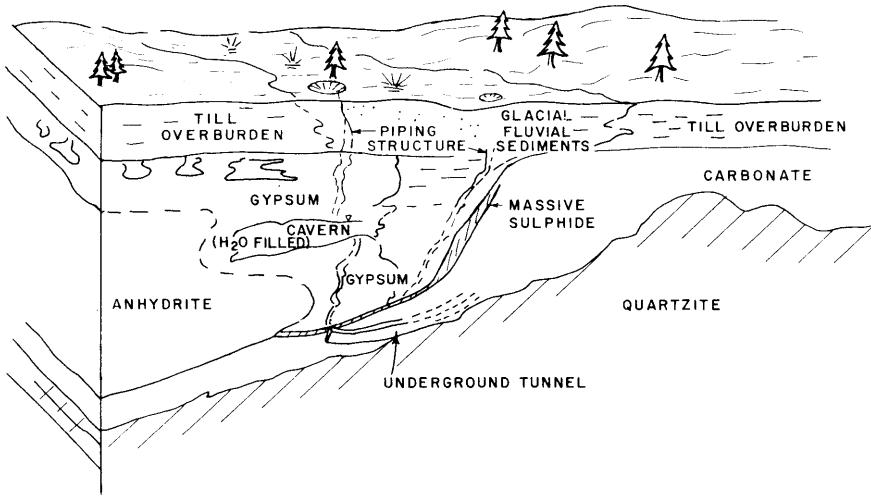
26

Figure 8 (b):   The water-bearing "pipe" is exposed when the round
                 is blasted. The heading floods with water, sand
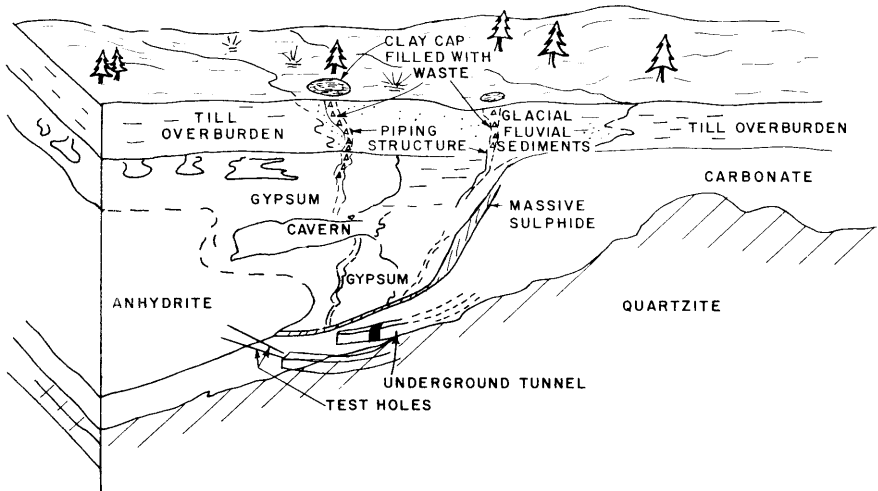   and mud. Sinkholes form on the surface.

Figure 8 (c):   The drift is pumped out and a reinforced concrete
                 bulkhead is built. The heading must go through
                 waste to bypass the water.

27

HYDROLOGY TEST PROGRAM

Solubility Test

The fact that gypsum is readily soluble in a matter of hours or
days was verified by filling two 159 litre drums, one with gypsum
rock and the other with anhydrite, running river water through
the drums and recording the weight loss. This test confirmed
that gypsum is readily soluble, whereas the anhydrite is
relatively stable. Evidence of solution fractures of channelways
in the gypsum was observed underground on at least three
occasions; in the 119 electrical substation, 118-3 heading, and
119-C heading, where minor flows or mere trickles of water
increased in a matter of weeks to between 30 and 60 l/s. As a
result of the solutioning effect, all water inflows encountered
in the gypsum were sealed immediately and all surface
diamond-drill holes cemented during exploration to prevent later
mining problems.

Sonar Survey

A sonar depth survey of the Gays River was performed to locate
sinkholes in the bed of the river. Martec Limited of Halifax
performed a bathymetric survey using a Furino Portable Echo
Sounder and a row boat (19). The survey identified seven
possible sinkholes in the bed of the Gays River. Four of these
were in an area of recent sinkhole activity. An attempt to trace
possible connections to the mine workings by dropping saltlicks
into the sinkholes was unsuccessful due to high chloride levels
in the river water caused by winter highway salting.

Phase I: Test Program

The test hydrology program (18) commenced in early November 1981,
and determined that "the underground water problems at Gays River
Mine occurred mainly as a result of a sediment-filled "trench"
that lies in contact with the dolomite reef host rock in much of
the ore zone". It was felt that the principal sources of
recharge to the now partially dewatered "trench" sediments were:

1. Vertical leakage resulting from the direct infiltration of
    precipitation and surface water bodies (the Gays River). It
    was thought that leakage through the thick clayey till was
    small and that more significant leakage occurs where the till
    has been partially, or perhaps wholly, replaced by permeable
    valley-fill sediments.

2. Underflow along the trench.

28

3. Lateral leakage of water from the evaporites, reef complex and Goldenville Formation.

4. Vertical solution-structure leakage, that although con-trolled to date with some difficulty, has the potential to provide very large inflows as conditions change with time or if a mining misjudgment is made.

A series of Exploratory Test Wells (ETW) were therefore proposed to establish the presence of water-bearing solution zones. Four drill sites at significant "re-entrant" channels along the reef were selected, with the wells located somewhat to the reefward side of the mapped limit of the solid evaporites. Also recommended was the installation of a proper recording weir to continuously monitor total mine outflow and the installation of orifice manometers and pump hour meters on individual outflows to gain a better understanding of water table changes. Construction of the weir and orifice manometers was completed and the selection of a well driller finalized by the end of 1981. Selection of the well driller was time consuming because rotary equipment and the capacity to drill wells to 75 cm diameter was considered essential. Previous experience in drilling large diameter wells in poor ground was also considered mandatory.

Exploratory Test Wells

The four ETW's were completed during the period January 15th to February 22nd, 1982. The wells were drilled at 25 cm diameter by mud rotary through the overburden and into the evaporite bedrock, when 20 cm casing was set. Drilling was then continued by air, with water rotary, to the quartzite basement. Yield testing was undertaken using air lift. Three of the wells, ETW#1, ETW#2, and ETW#3, suggested that the "trench re-entrants" were generally favourable sites for dewatering wells, with sites ETW#1 and ETW#3 favourable for high yield dewatering wells (+30 l/s). ETW#4 was drilled and cased to bedrock without encountering solid evaporites and later efforts to pull the casing in an attempt to develop the well were unsuccessful. Reports of dirty water dis-charge from DW#3 during drilling of ETW#1, ETW#2, and the 118 boreholes appear to indicate extensive connections between the cavernous zones. Overall, the well drilling was slow, difficult and costly, since the depth of overburden, karst surface of the gypsum bedrock and successive zones of cavities necessitated casing or cementing-off in order to obtain the return of circu-lating fluid and cuttings and prevent hole caving.

At the same time as the ETW's were being drilled, underground
crews were completing the new 118 sump and pump station in the
deepest part of the mine. This station had a pumping capacity of
approximately 200 1/s, and it was decided to observe the effects
of pumping from this area before recommending dewatering wells at
the better ETW sites.

The 118 pump station was made operational on April 16th, allowing
underground drains in the area to be opened fully and additional
drains to be drilled. During the remainder of April and through
May 1981, the total pumping from underground increased to around
250 1/s, with efforts continuing to increase it to a maximum of
400 1/s using the 118, 119, and 101 pump stations. Although
pressures in the 118 area dropped from 0.7 MPa to below 0.4 MPa,
from mid April to the end of May, and inflows through the drains
decreased, efforts to increase the total outflow were not
successful. For example, at 0.7 MPa, two drains exceeded the
capacity of the 118 pump station while at 0.4 MPa, seven drains
fed the pumps at about 75% capacity.

With the increased drainage to underground, the water table
appeared to drop below the cavity zone that was supplying DW#3,
and the pump in this well shut off because of low water sensors
and sanded up. The pump was subsequently pulled and the well
used as an observation point. The increased drainage to
underground resulted in extensive sinkhole activity in the area
over 118 and 119 with some new sinkholes forming within the
floodplain of the Gays River. Obviously, even though filled,
these contribute to recharge of the underlying strata whenever
the river overflowed its banks. The underground drains appeared
to be connected with an extensive horizontal and vertical
solution channel system with various soil piping structures as
evidenced by observation well response and the location of
sinkhole developments. Since all the sinkholes recorded during
the mining operations occurred within the mapped area of
glacial-fluvial sediments, this geological unit may be even more
of a contributing factor in recharge than originally believed.
The observation well network and underground pressure readings
appeared to indicate a rapid rebound of the water table in
response to any blockage of drains or extended surface
precipitation, suggests that a limited volume "capiliary" system
was being recharged.

A second Martec Bathymetric Survey performed five months after
the first survey (May 1982) not only succeeded in relocating the
previous sinkholes in the bed of the river, but indicated two new
ones. The two new holes were also located in the area of recent
sinkhole activity.

This apparent activity in the river bottom, in an area where sinkholes were forming in response to increased drainage from underground, had serious implications, at least, for the areas of the deposit overlain by fluvial sands and the river.

As a result of the uncertainties of ever being able to achieve the necessary degree of mine dewatering, it was decided to suspend further underground operations.

CONCLUSIONS

In comparison with some Mississippian lead/zinc deposits, the pumping rates at Gays River were not excessive. A significant drawdown of the water table was achieved at moderate pumping rates through a combination of surface dewatering wells and underground drains. The 250 1/s pumped is considerably less than the 375 1/s reportedly pumped from the Newfoundland Zinc Mine in 1976, after a similar period of operation and which subsequently rose to 1260 1/s by 1979. However, the dewatering scheme at Gays River Mine was achieved to a considerable degree by trial and error. The water-bearing pipe structures proved rather elusive and their rapid rebound makes the feasibility of achieving adequate dewatering over the entire orebody uncertain. In addition, the extent of the glacial-fluvial sediments in contact with the Karst topography or soil pipes and the solubility of the evaporites remain major uncertainties with respect to achieving and maintaining secure dewatering of the underground workings.

The unique and complex geological features of the Gays River deposit area make a solution to the hydrologic problems exceedingly difficult. Also, because of these features, most of the commonly used techniques are not applicable or economic. It would require much more than simply drilling a number of wells and pumping more water; diversion of the Gays River may be necessary as well as the establishment of a grout curtain between the ore host rock and the overburden, or even grouting the ore in advance of mining to reduce inflows to the point where economical mining can be undertaken.

REFERENCES

1. Stevenson, I. M.; "Truro Map Area, Colchester and Hants Counties, Nova Scotia". Geological Survey Can. Mem. 297, 1958.

2. MacEachern, S. B. & Hannon, P.J.F.; "The Gays River Discovery - A Mississippi Valley Type Pb/Zn Deposit in Nova Scotia". Bulletin, Canadian Institute of Mining and Metallurgy, Vol. 67, No. 750, 1974, pp. 61-66.

3. Hannon, P.J.F. & Scott, F.; "Lead-Zinc Exploration in the Gays River District of Nova Scotia". Society of Mining Engineers, A.I.M.E. Transactions,, Vol. 258, 1975, pp. 209-212.

4. MacLeod, J. L.; "Diagenesis and Sulphide Mineralization at Gays River, Nova Scotia". Dalhousie University, Halifax, Nova Scotia, Unpublished B.Sc. Thesis, 1975.

5. MacLeod, J. L.; "The Effects of Diagenesis on Base Metal Mineralization Within the Mississippian Carbonate Complex at Gays River, Nova Scotia, Canada". In print, Proceedings of the IX, I.C.C. Conference on Carboniferous Stratigraphy, Urbana, Illinois; May 1979.

6. Hatt B.; "An Interpretation of the Carbonate Geology Exposed in the Decline at Gays River, Nova Scotia". Unpublished M.Sc. Thesis, Dalhousie University, Halifax, Nova Scotia, 1978.

7. Giles, P. S. & Ryan, R. J.; "A Preliminary Report on the Stratigraphy of the Windsor Group in the Eastern Minas Sub-Basin, Nova Scotia". N. S. Department of Mines, Report 76-2, 1976, pp. 100-105.

8. Boehner, R.; "Multiple Repetition of a Single Carbonate Horizon in the Lower Part of the Windsor Group, Northwest Kennetcook Map Area". N. S. Department of Mines, Report 77-1, 1977.

9. Palmer, W. J.; "Preliminary Discussion on Mineralization of the Gays River Carbonate Complex - Abstract". GAC Annual Meeting, Halifax, Nova Scotia, Field Trip 22 Guidebook, 1980, pp. 29-34.

10. Akande, S. O.; "Some Aspects of the Genesis of Lead-Zinc Mineralization in Central Nova Scotia - A Proposal". Unpublished Written Communication, 1980.

11. Akande, S. O.; "Stratiform and Vein Type Lead-Zinc Ores at Gays River: Metallogenic Implications - Abstracts". GAC-MAC Annual Meeting, Halifax, Nova Scotia, 1980.

12. Zentilli, M., Doe, B. R., & Delevaux, M.; "Isotopic Composition of Lead in Some Nova Scotia Galenas: Metallogenic Implications - Abstracts". GAC-MAC Annual Meeting, Calgary, Alberta, 1982.

13. Akande, S. O. & Zentilli, M.; "Genesis of the Gays River Pb/Zn Mineralization Reconsidered in the Light of Geologic and Fluid Inclusion Studies". (Abstract) GAC-MAC Annual Meeting, Winnipeg, Manitoba, 1982.

14. Groves, A. W.; "Gypsum and Anhydrite". Overseas Geological Survey, Mineral Resources Division (Great Britain), 1958.

15. Hem, J. D.; "Study and Interpretation of the Chemical Characteristics of Natural Water". U. S. Geological Survey Water-Supply Paper - 1473, 1970.

16. deMille, G; "Personal Communication". 1981.

17. Dames & Moore; "Written Communication". Mine Files, 1974, 1980, 1981.

18. Leggette, Brashears and Graham, Inc.; "Written Communication". Mine Files, 1982.

19. Martec Limited; "Gays River Survey". Written Communication, Mine Files, 1981, 1982.