CHAPTER 2

SEDIMENTARY GYPSUM DEPOSITS

STRATIGRAPHY AND GEOLOGY OF THE STANFORD RANGE

Gypsum in the Stanford Range occurs in rocks of Devonian age (Figure 7). Early work by Henderson (1954) assigned the name Burnais Formation to a sequence of evaporites and associated carbonate rocks and Harrogate Formation to the overlying limestone and shale sequence. Leech (1958, 1960) retained the same nomenclature and added the term "basal Devonian unit" to a sequence of quartzites, argillaceous limestone and limestone of Devonian age underlying the evaporites. More recent work by Souther and Halford (1967) proposed the term "Cadared Formation" for a sequence of dolomites, sandstones and limestones that is, in part, stratigraphically equivalent to the Burnais Formation and possibly part of the basal Devonian unit. They retained the name Harrogate Formation. These stratigraphic relationships are shown in Figure 8.

This study attempted to delinate areas underlain by gypsum from those underlain by carbonate rocks. Much of the carbonate strata previously included in the Burnais Formation are now tentatively assigned to either the Cedared or Harrogate formations. This designation is primarily based on lithological similarities.

Devonian strata uncomformably overlie or are in structural contact with the Ordovician-Silurian Beaverfoot-Brisco Formation. This unit consists primarily of thin to medium-bedded light grey dolomite and limestone. Ovular chert nodules and lenses in a carbonate matrix are characteristic of the unit. The upper contact was not seen in the study area.

Strata of the basal Devonian unit were only observed in the Coyote Creek area. It consists of orthoquartzite and sandstone low in the section and limestone, argillaceous limestone, dolomite and minor shale in the upper part. Argillaceous limestones are easily recognized by their pale maroon to pale green colour. Lithologically similar strata, tentatively assigned to the Cedared Formation, outcrop in the Windermere Creek area west and northeast of the Elkhorn deposits. Limestone and dolomite in the upper part of the section are generally grey to dark grey, thin to medium bedded, aphanitic and void of fossils.

The Cedared Formation, at its type locality, consists of a sequence of dolomite, limestone, argillaceous limestone, mudstone, sandstone and breccia. These rocks are typically grey to yellowish brown and weather light grey, light yellowish grey and light brownish grey to light brown (Belyea and Norford, 1967). In the Stanford Range the Cedared Formation comprises dolomite with minor limestone and argillaceous limestone. These rocks are generally light grey to grey and weather grey to pale maroon and green. They are thin to medium bedded and aphanitic to finely crystalline. No fossils were found.

The Burnais Formation is restricted to an evaporite sequence consisting of gypsum and anhydrite that occurs at a number of localities throughout the Stanford Range. Although anhydrite does not outcrop, it occurs in drill holes at depths ranging from 20 to 40 metres. Very little is known about the thickness of the anhydrite as very few holes penetrate its entire thickness. A black fetid limestone and thin grey aphanitic limestone bands in fault contact with the gypsum are also included in the Burnais Formation. Estimates of stratigraphic thickness range from 50 to 100 metres or more, with the thickest sections occurring in the Ulm/Germaine Creek area. There is a general thinning of the formation southward towards Coyote Creek where thickness rarely exceeds 40 metres. This study suggests gypsum deposits are not as widespread as previously thought. Much of the area previously mapped as Burnais Formation is now interpreted as underlain by carbonate rocks of the Cadomed and Harrogate formations.

Seven areas underlain by the Burnais Formation were identified by Henderson in the Stanford Range. Leech (1958) mapped the formation over a large area near the Lussier River. Much of the subcrop of the Burnais Formation is inferred from the presence of sinkholes; the scarcity of outcrop makes interpretation of the gypsum distribution extremely difficult.

Gypsum throughout the Stanford Range is typically laminar to thin bedded (Plate 1), with laminations and bedding varying

in thickness from a fraction of a millimetre to 4 millimetres. Laminations are generally crenulated or intricately folded. The colour of the gypsum varies from white through various shades of grey to occasionally black. Pale brown to pale brownish grey laminae are very often present. White selenite is common as massive blebs but may also occur as well-formed crystals or along fractures and fault surfaces. Cross-laminations and cut-and-fill structures, indicative of periodic high-energy events in an overall shallow-water facies, are observed locally. Native sulphur is present in trace amounts at many localities, most commonly as crystalline masses associated with selenite along fractures. Occasionally it is smeared along slickenside surfaces giving the impression of greater abundance.

Gypsum deposits are more structurally complex than the enclosing carbonate rocks. Some of the small scale structural features may be the result of soft sediment deformation occurring at the time of deposition. Others are interpreted as enterolithic (Plates 2 and 3) and related to swelling and expansion during conversion of anhydrite to gypsum. This process involves a volume increase of 30 to 50 per cent. Microfaults are also believed to be the result of expansionary forces.

Large scale concentric, open and chevron folds preceeded the conversion of anhydrite to gypsum as their contact crosscuts fold axis of these folds. Transverse faults with an east-west orientation appear to be a late stage event and may even post date the formation of the gypsum. This late stage faulting may

account for the large fluctuation in thickness of gypsum north and south of the fault in the Elkhorn Quarry.

Anhydrite which is distinguished from gypsum by its hardness and light blue colour is rarely observed in outcrop. In the Windermere Creek area anhydrite occurs at an average depth of 30 to 40 metres while in the Lussier River area it occurs at a depth of 20 to 25 metres. Very often there is an accumulation of salts at or very near the anhydrite-gypsum contact.

Gypsum/anhydrite evaporite deposits commonly form in either standing bodies of water or within the vadose zone and upper phreatic zone on supratidal flats and desert playas. Characteristics of the former include laminated or bedded evaporites and soft sediment deformation with small faults. They are usually void of fossils. Based on these criteria it can be interpreted that gypsum deposits in the Stanford Range probably formed in a standing body of water. Water depths were probably shallow ranging from a few centimetres to a few metres. This is evidenced by the presence of cross-laminations cut and fill strucutres and rip up breccias. The presence of selenite is also indicative of a shallow water environment.

The Burnais and Cedared Formations are interpreted by Belyea and Norford (1967) to have been deposited in a gently subsiding basin. Accumulation took place in a long, relatively narrow depression. The Cedared Formation was probably deposited in a

tidal flat environment that may have been periodically emergent. Deposition took place on a fairly broad shelf west of the Western Alberta Ridge (Norford, 1981). Contemporaneous deposition of the Burnais Formation evaporites was limited to areas with restricted circulation.

The Harrogate Formation is the youngest Devonian unit in the Stanford Range. It consists of a sequence of dark grey to black, typically nodular limestones. Minor shale and dolomite are present locally. The nodular limestone unit, which can be traced throughout the study area, is a useful marker horizon. Fossils, mainly brachiopods, were found at two localities, near the Elkhorn quarry and in the Coyote Creek area. Deposition of the Harrogate Formation took place in a deeper water environment as is exemplified by the presence of open-marine carbonates and shales (Norford, 1981).

In the Coyote Creek - Lussier River area, the Devonian sequence is overlain by a shale unit and carbonate strata of the Banff Formation. These rocks are Mississippian in age.

Sinkholes, although commonly associated with gypsum deposits can also be formed in carbonate terrains. It is possible for sinkholes to form along contacts between carbonate rocks of varying solubility. Distinct linear trends of sinkholes are therefore generally indicative of contact or fault zones. This characteristic is observed often in the Stanford Range.

Sinkholes that have formed directly over gypsum tend to have a random pattern. This is most evident in the vicinity of Coyote Creek. Areas where there is no distinct pattern to the distribution of sinkholes may provide good exploration targets.

PETROLOGY AND PETROGRAPHY

Textures observed in thin section from samples collected in the Stanford Range are similar to those of alabastrine secondary gypsum observed and described by Holliday (1970), Mossop and Shearman (1973) and Ogniben (1957). Alabastrine textures are defined as those in which individual grains are poorly defined or diffuse and have irregular or undulose extinction. With further recrystallization well-defined intricately interlocking equidimensional anhedral grains form. Gypsum varies from granoblastic consisting of very fine-grained anhedral to subhedral crystals to mosaics of ill defined crystals and anhedral crystals. Relic anhydrite is only rarely observed. In some thin sections subhedral crystals, generally coarser-grained, are observed. These are interpreted to have formed in the late stages of the hydration and recrystallization process. In those specimens in which anhydrite is prevalent, one can observe the initial stages of the conversion to gypsum. This conversion may be in the form of alteration of individual crystals or in the form of veinlets of gypsum forming along fractures or microfaults.

GYPSUM DEPOSITS

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overburden and carbonate strata of the Cedared Formation (Minfile Number: 082JNW004). Drilling on the ridge north of Windermere Creek intersected gypsum to depths varying from 17 to 43 metres. Underlying the gypsum was anhydrite (Clow, 1980). Gypsum is similar to that observed elsewhere in the area. Its quality varies from 74 to 94 per cent, averaging better than 85 per cent gypsum.

Further north a small lens of gypsum outcrops south of Stoddart Creek (Minfile Number: 082JNW005). Here the rock is of lower quality, containing 75 per cent gypsum (F.W. Jarret, Westroy Industries Ltd., personal communication, 1988). Gypsum, which can be traced intermittently along strike for approximately 1 kilometres is confined to a downdropped fault block that abuts against the Redwall Fault to the east. The contact between the gypsum and the fault is not observed. Gypsum is cream to pale grey and laminated. In thin section it is seen to be composed of very fine-grained, anhedral to diffuse gypsum grains. Also present are distinct gypsum, probably selenite stringers. Dolomite occurring as a very fine-grained clastic component is the principal impurity with trace amounts of quartz and orthoclase also present. No gypsum is known north of Stoddart Creek.

KOOTENAY RIVER - NINE MILE CREEK AREA

In the Kootenay River - Nine Mile Creek area gypsum outcrops

extensively on the west side of the river north of the bridge at kilometre 10.5 on the Kootenay River logging road (Figure 11, in pocket). Gypsum is very well exposed in an area approximately 1.5 kilometres in length across an average width of 400 metres over heights up to 30 metres. Bedding generally strikes north to northweasterly with moderate to steep dips to the east. The gypsum is pale grey to grey in colour and is typically laminated to thin bedded. Pure white gypsum is present locally. To the west the gypsum is in fault contact with older rocks; to the east it disappears under extensive overburden in the Kootenay River valley. A minor amount of gypsum has been produced from a small quarry at the north end of this deposit (Little Jean: Minfile Number 082F 050), where gypsum has been exposed in trenches and other workings over a stratigraphic interval of approximately 125 metres. Shipments of gypsum from this location which contained 85 per cent or less gypsum were made by Western Gypsum Products Limited in 1957.

There are several large exposures of gypsum along the east bank of the Kootenay River and in the immediate vicinity of Nine Mile Creek. Away from the valleys of these two waterways outcrop is scarce or absent. Overburden cover in excess of 25 metres thick has been determined from diamond drilling done along the access road into Nine Mile Creek (Blender, 1988). The gypsum is intercalated with carbonate strata of the Cadared Formation. A black fetid limestone of the Burnais Formation is present in more westerly localities. Nodular limestone of the Harrogate Formation is also present. East of the Kootenay River the structure is more

complex. Bedding strikes east to northeasterly with moderate dips to the northwest, north and south. Structural relationships east and west of the Kootenay River suggest that a synclinal axis, with or without associated faulting, may be present.

In the Nine Mile Creek area laminated to thin-bedded gypsum varies from cream to pure white in the north to the more typical pale grey to grey in southerly exposures. Northern exposures contain abundant white selenite with lesser rounded gypsum fragments and a few angular limestone fragments. To the south the gypsum retains its laminar appearance but does not contain any gypsum or carbonate fragments. Bedding thickness ranges up to 5 centimetres, but thicknesses less than 1 centimetre are more usual. Native sulphur was observed in a single outcrop immediately north of Nine Mile Creek. The quality of the rock is variable with gypsum content varies from 44 to 94 per cent (Henderson, 1954).

LUSSIER RIVER - COYOTE CREEK AREA

The southernmost exposures of gypsum in the Stanford Range occur in the Lussier River-Coyote Creek area (Figure 12, in pocket). In the Lussier River valley the majority of occurrences are located east of the river. Extensive and very thick overburden preclude tracing the gypsum over any significant distance. Where observed, the gypsum is steeply dipping to vertical. Faulting may have played an important role in the

localization and preservation of these deposits. The dominant structural feature in the area is a north trending syncline with shallow dipping limbs. The axis of this syncline is located along the height of land separating the Lussier River and Coyote Creek. Gypsum is present along both limbs of the syncline.

Isolated occurrences of gypsum have been traced from a locality approximately 2 kilometres north of the junction of the Lussier River and Coyote Creek south to the northern boundary of the Top of the World Park. A single gypsum outcrop is present east of Coyote Creek at the same latitude as the Lussier River Quarry. Further to the south three new occurrences of gypsum were located immediately east of the height of land separating the Lussier River from Coyote Creek. These showings were first reported by Dutrenchuk (1989) although nearby sinkholes were mapped by Leach (1960). Two of the gypsum occurrences are located on a logging road locally known as Branch F; the third outcrops north of the westernmost of these two showings.

Following are descriptions of the various deposits and occurrences present in the Lussier River-Coyote Creek area.

LUSSIER QUARRY Minfile Number: 082JSW009

Latitude: 50°03'00" Longitude: 115°31'00" NTS: 82J/4E

Gypsum is presently being mined from a quarry located on the Lussier River approximately 2.5 kilometres south of its confluence with Coyote Creek (Plate 7). The quarry which began

producing in 1984 is owned by Domtar Inc. and operated by Domtar Gypsum. Original reserves were calculated to be approximately 7 million tonnes (Rodgers and Kovacs, 1984). Gypsum is hauled a distance of 32 kilometres over logging roads to a plant situated at Canal Flats. Unlike the quarries on Windermere Creek there is no primary crushing of the gypsum at the quarry site. The crushing plant is located along a railroad spur at Canal Flats.

The deposit, which is exposed in outcrop across a width of 195 metres and over a vertical height of approximately 100 metres, occurs in a northeast-trending anticline. It is truncated to the south by a fault and probably abuts a fault to the north, although evidence for this is lacking. Carbonate strata of the Cadorer Formation outcrop immediately north and south of the deposit but nowhere are contact relationships exposed for observation. The deposit is overlain by nodular limestone of the Karrigate Formation. Structure within the deposit is complicated by numerous faults with minimal displacement and intricate small-scale enterolithic folds. A fault with considerable but undeterminable displacement near the southern end of the quarry has a carbonate band adjacent to it. These structures are the locus of sinkholes and other karst features within the deposit.

Gypsum varies in colour from pale grey to black with some cream to white laminae present. It is very well laminated with laminae ranging in thickness from 0.1 to 4 millimetres. Locally thicker laminae are present. White selenite occurs as blebs along

fractures and fault zones. Native sulphur is present locally but is rare as is pyrite. Anhydrite occurs as pods or thin layers within the deposit. These increase in frequency and extent with depth (Rodgers and Kovacs, 1984).

In thin section the gypsum is observed to have a fine-grained granular texture. The texture varies from distinct well formed grains to those having diffuse grain boundaries giving the rock a felted appearance. Carbonate material, generally in the form of dolomite constitutes approximately 10 to 15 per cent of the rock while minor amounts of quartz and lesser anhydrite are also present.

BEAVER (LUSSIER SOUTH) Minfile Number: 082JSW017

Latitude: 50°02'15" Longitude: 115°30'15" NTS: 82J/4W

Why do you have to look for this info for some deposits & not others.

The Lussier South quarry is located 3 kilometres south of Coyote Creek and 1025 metres south of the presently producing gypsum quarry on the Lussier River. There has been some minor production from this quarry although details to the amount produced are lacking.

Gypsum is exposed along the quarry walls across a width of 80 metres. It is laminated to thin-bedded, pale grey to grey with some dark grey laminae present. At the south end of the outcrop numerous faults and some brecciated gypsum is present. Minor amounts of selenite as blebs and stringers occur throughout.

Trace amounts of native sulphur were also observed. Dolomite and minor amounts of quartz and anhydrite also occur. Trace amounts of albite, chlorite and syngenite, a hydrous, calcium-potassium sulphate salt, were identified by x-ray diffraction study.

AMOS Minfile Number: 082JSW004

Latitude: 53°05'15" Longitude: 115°32'10" NTS: 82J/4E

Two small gypsum outcrops are exposed along the east bank of the Lussier River in a road cut, 2.2 kilometres north of the junction of Coyote Creek and the Lussier River. Outcrop is rare except for a third outcrop of gypsum to the south along the river and two outcrops of limestone east of Coyote Creek. Sinkholes are common. A seismic survey completed in this general area in 1961 indicated that the thickness of overburden varied from 15 to 76 metres (Miller, 1961). Drilling by Dunbar in 1987 (Blender, 1987) confirmed the presence of a thick overburden cover.

Where exposed the gypsum is pale grey, grey and pale brownish-grey. It is laminated with the laminae contorted and folded. Some brecciated gypsum is present locally. Drilling in the immediate vicinity of these outcrops failed to intersect any gypsum. Holes that were able to penetrate the overburden intersected either anhydrite or limestone (Blender, 1987). Gypsum appears to be restricted to a small area along the bank of the Lussier River. To the north limestone is present while anhydrite replaces gypsum to the northeast. There may be potential for the gypsum to extend southwards to the southernmost of the gypsum

outcrops.

East of the Lussier River logging road several sinkholes are randomly distributed. While there may be potential for the presence of gypsum, limestone is present in at least part of the area (Blender, 1987).

GYPIT Minfile Number: 082JSW019

Latitude: 50°02'00" Longitude: 115°28'00" NTS: 82J/3W

A solitary outcrop of gypsum is exposed along a roadcut immediately east of Coyote Creek, approximately 5 kilometres south of the junction of the Lussier and Lower Coyote Creek logging roads. Gypsum is present over a length of 115 metres over thicknesses varying between 10 and 20 metres. This occurrence is owned by Domtar Inc. and was the subject of an exploration program in 1987. Trenching and percussion drilling using an air trac drill failed to extend the gypsum beyond the outcrop limits (Blender, 1987).

The gypsum is dark grey to black with some pale grey and cream coloured laminae present. It is laminar with the laminations being contorted and folded. Small scale faults with negligible displacement are also common. On a larger scale it appears that the gypsum occurs on the southern limb of an east-west trending anticline.

A granular texture consisting of very fine-grained to fine grained gypsum is observed in thin section. Associated with the gypsum is very fine-grained dolomite with minor amounts of anhydrite and quartz. Traces of an unidentified amphibole mineral were identified by x-ray diffraction.

Contacts with surrounding rock are not exposed. A small outcrop consisting of dark grey to black dolomite occurs to the northwest. The author has assigned this dolomite to the Cedared Formation.

TRUROC Profile Number: 092P/SW/021

Latitude: 51°0'30" Longitude: 115°31'00" NTS: 82J/4E

Gypsum is exposed along the east shore of the Lussier River 2.5 kilometres south of the junction of Rose Creek and the Lussier River. It occurs in steep bluffs in excess of 30 metres high over a length of 200 metres. Sinkholes on both sides of the river suggest that gypsum may be present over a much larger area than observed in outcrop (Figure 13).

The property on which the gypsum occurs is owned by Westroc Industries Limited. Past exploration has consisted of diamond drilling, geological mapping (Korum, 1980) and geophysics (Reimchen and Bakker, 1982).

The gypsum is pale grey and thinly bedded to laminar. Bedding and laminations are generally steep dipping and very

often severely contorted. Fault related breccia zones are observed in both outcrop and periodically in drill core. Native sulphur is present in trace amounts. Results of the drill program indicate that the gypsum is approximately 33 metres thick in its centre and 20 metres thick near its northern end.

Overlying the gypsum is a black to dark grey limestone of the Harrogate Formation. To the south it abuts against a calcareous tufa that is probably a facies equivalent. North of the gypsum, is a black aphanitic, steeply dipping limestone of the Cedared Formation. Its contact with the gypsum is not observed. Faulting is common and may mark the contact between the gypsum and this limestone.

Korum (1990) suggested that there is a potential for 40 million tonnes with a purity in excess of 80 per cent gypsum. A more conservative estimate by the author suggest a potential for 20 million tonnes. No gypsum has been observed on the west side of the Lussier River at this locality. Drilling was unsuccessful in penetrating the overburden in this area. While the presence of sinkholes suggests that gypsum may be present at depth it is very doubtful that this gypsum, if present, can be exploited.

BRANCH F Minfile Number: 082GNW071

Latitude: 49°58'10" Longitude: 115°27'00" NTS: 82G/14W

Gypsum, tentatively assigned to the Burnais Formation, is