Open File Report 1989-04

PROPOSAL FOR SCIENTIFIC DRILLING ON THE STEEN RIVER STRUCTURE, NORTHWESTERN ALBERTA.

John Wilson, Willem Langenberg (Alberta Geological Survey), Lynn Jeffries (Husky Oil), Jeff Tooth (Maxus Energy), Richard Grieve (Geological Survey of Canada) and Zoltan Berkes (University of Alberta)

INTERNATIONAL SETTING

One of the current major international debates in the earth sciences is to what extent major impact events can lead to a deterioration of the global environment through instantaneous change. This debate is focussed largely on the Cretaceous-Tertiary boundary event and whether or not there is a periodicity in the marine extinction and impact records (e.g. Geol. Soc. Amer. Sp. Paper190, 1982; Global Catastrophes and Earth History, 1988). It is a public debate being the subject of articles in the general scientific (e.g. Kerr, 1988) and the popular media.

The Steen River Structure (SRS) is a world class example of a complex meteorite impact structure. Its burial by thin Cretaceous and recent sediments has preserved the structure from the modifying effects of erosion. Pristine craters are at a premium as they provide the only ground truth constraints on the effects of major impact events on the Earth. They also provide data on planetary impact cratering, which constitutes a major, if not dominant, geological process in early planetary history.

In the case of the SRS the entire melt sheet is probably preserved. There is only one other known example of a completely preserved melt sheet, at Boltysh in the Ukraine. The Boltysh structure is of a similar age to the SRS (100+5my and 95+7my respectively) and they are of the same size (25 km). Recently, Canada and the U.S.S.R. carried out a joint study of Boltysh (Grieve et al., 1987), and currently, international interest is focussing on its precise age and the nature of the impacting body. The melt sheet at Boltysh has been extensively drilled by the U.S.S.R. and represents an excellent case for a comparative study with the SRS. This would be particularly timely since the apparent similarity of these two structures has been recently cited as evidence for a peak in cratering at 100 my, and to suggest that the Earth has been subject to periodic cometary showers (e.g., Alvarez and Muller, 1984). If this proves to be the case, then can the "SRS cratering event" be related to postulated Cretaceous global change?

The SRS also has intriguing similarities to the recently discovered Montagnais structure. This structure occurs on the Scotian Shelf and is the only known example of a marine impact crater. The SRS apparently contains an anomalous zone of brecciated rocks within the melt sheet (Winzer, 1972), similar to that found at Montagnais (Jansa and Pe-Piper, 1987). Given its age, the SRS could have formed in the Western Cretaceous Interior Seaway. Montagnais has recently been surveyed geophysically and is the subject of proposed ODP drilling. It would thus form another site for comparative studies with the SRS.

If the SRS is a marine crater then its presence within a sequence of marine sediments gives us an opportunity to study the regional effects of the impact by studying the stratigraphic column regionally. This would provide constraints on models of ejecta particle size distribution and related tsunami-like effects, which are needed for evaluating various scenarios associated with the proposed Cretaceous/Tertiary boundary event.

In addition to the purely scientific benefits of a study of the SRS, there is a growing awareness amongst the international exploration community that buried impact structures may provide good structural traps for hyddrocarbons. Already there is oil and gas production from the Red Wing Creek structure in South Dakota and the Viewfield structure in Saskatchewan. The association of hydrocarbons with the SRS is well known, and a model for their trapping and maturation would add impetus to the recognition and exploitation of this and other buried impact features.

Exploration for hydrocarbons within and around the SRS has left a legacy of geophysical data which will enable us to create a solid framework of geological data within which the research drilling can be carried out. The final model generation will, therefore, be based on a greater overall wealth of data than any other previous work on impact sites of this size.

This study provides an almost unique opportunity to study a large, recent impact structure in a sedimentary basin setting. Recent scientific and public interest in impacts as agents of environmental and ecological change in the earth's history make the study of the SRS timely. The results to be gained from a scientific drilling program on the SRS will add to our knowledge of impact events on an international scale and give us a clearer understanding of the role of extraterrestrial events in the history of our planet.

DESCRIPTION

The Steen River Structure (SRS) is located in northwestern Alberta, approximately 115 km NNW of the town of High Level and 710 km from Edmonton (Figure 1). The structure has no surface expression, but was intersected by chance during petroleum exploration drilling in the 1960's. Regionally, the SRS lies predominantly within the Great Bear magmatic arc basement terrain. It is cut by the fault which separates the Great Bear from the Hottah accreted terrain and lies very close to the subsurface extension of the Great Slave Lake shear zone (Figure 2).

The structure itself consists of a central uplift surrounded by a rim syncline and an outer raised rim (Figure 3). The outer diameter of the SRS is approximately 25 km. The central block consists of basement upthrust 1100 m above the regional level. The rim syncline is downthrust 200 to 600 m below regional levels, and the outer raised rim is upthrust 20 to 50 m. Thus, there is a relative throw of 1700 m between the center and parts of the rim syncline. The structure is surrounded by an irregular disturbed zone extending up to 30 km from the raised rim. This disturbed zone appears to be the result of doming and is cut by normal faults producing local horsts and grabens. Figure 4 shows a schematic cross section of the main features of the structure.

Published work on the SRS is sparse (Carrigy and Short, 1968 and Winzer, 1972), and is primarily concerned with the evidence for shock metamorphism seen in basement core from the central uplift. The unaltered basement is not cored but probably is an amphibolite, biotite gneiss or granitoid. The altered basement has a gneissic texture and is cut by breccia zones. In thin section, quartz, amphibole, feldspar and biotite all show evidence of shock metamorphism. In addition to fragments of the country rock, the breccia zones contain both devitrified and fresh glassy fragments. Zones of partly devitrified, glassy rock are also common.

Examination of downhole logs in the area of the SRS show a sequence

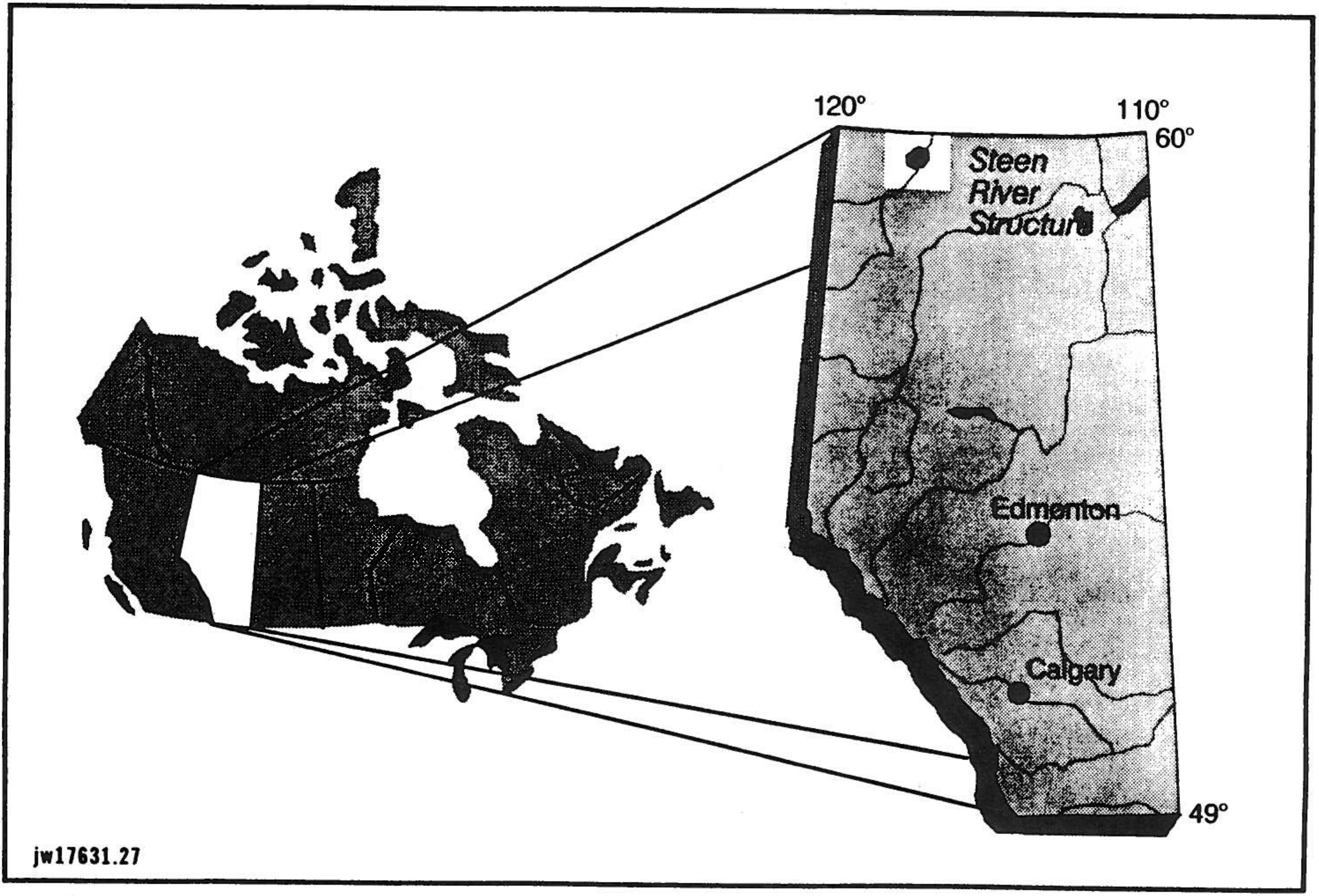
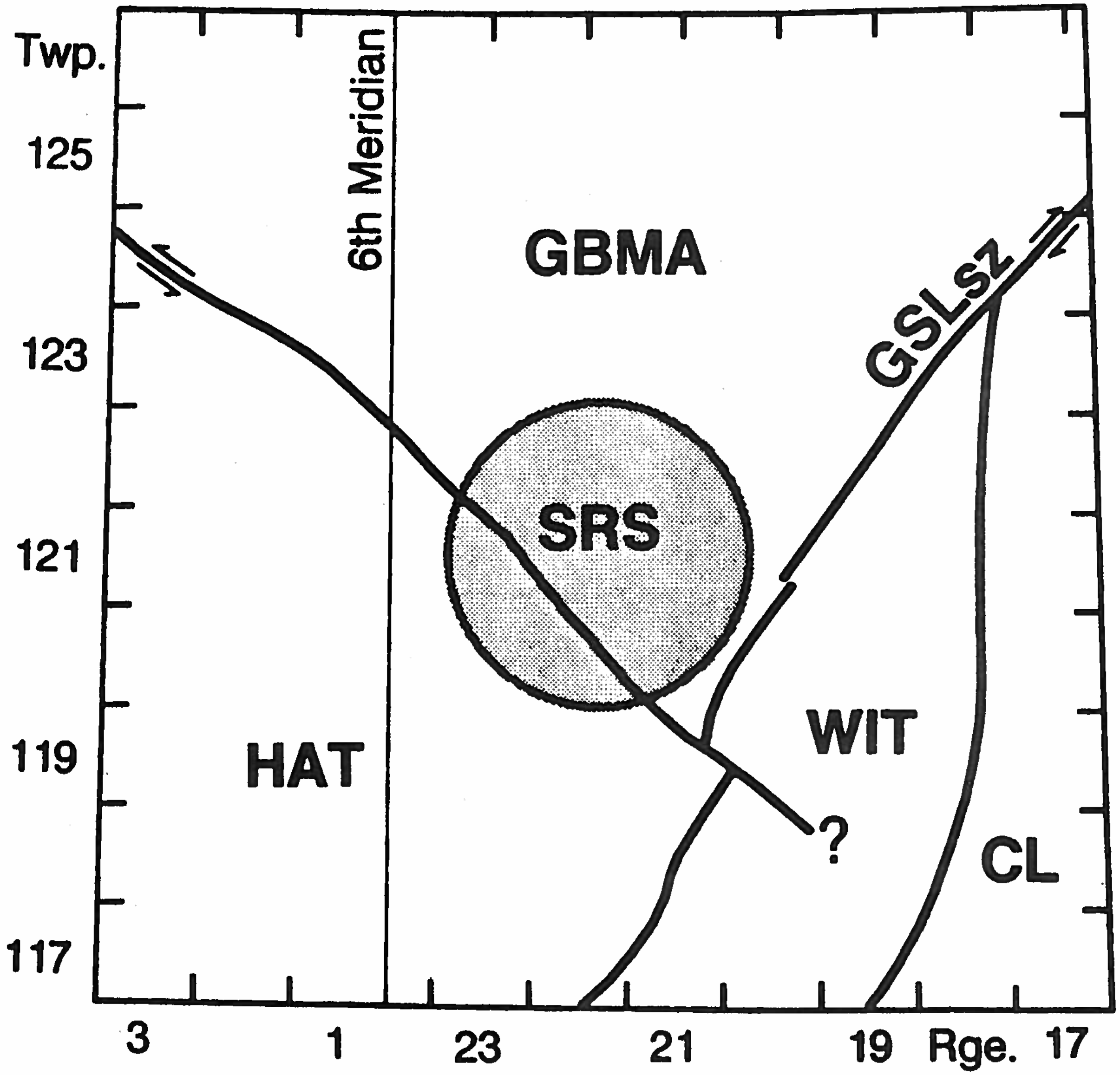

120°
110°
60°
Steen River Structure
Edmonton
Calgary
49°
jw17631.27

FIGURE 1



Steen River Structure

GBMA	Great Bear Magmatic Arc
HAT	Hottah Accreted Terrain
WIT	Wilson Island Terrain
CL	Chinchaga Low
GSLsz	Great Slave Lake shear zone
SRS	Steen River Structure

(after Hoffman 1987)

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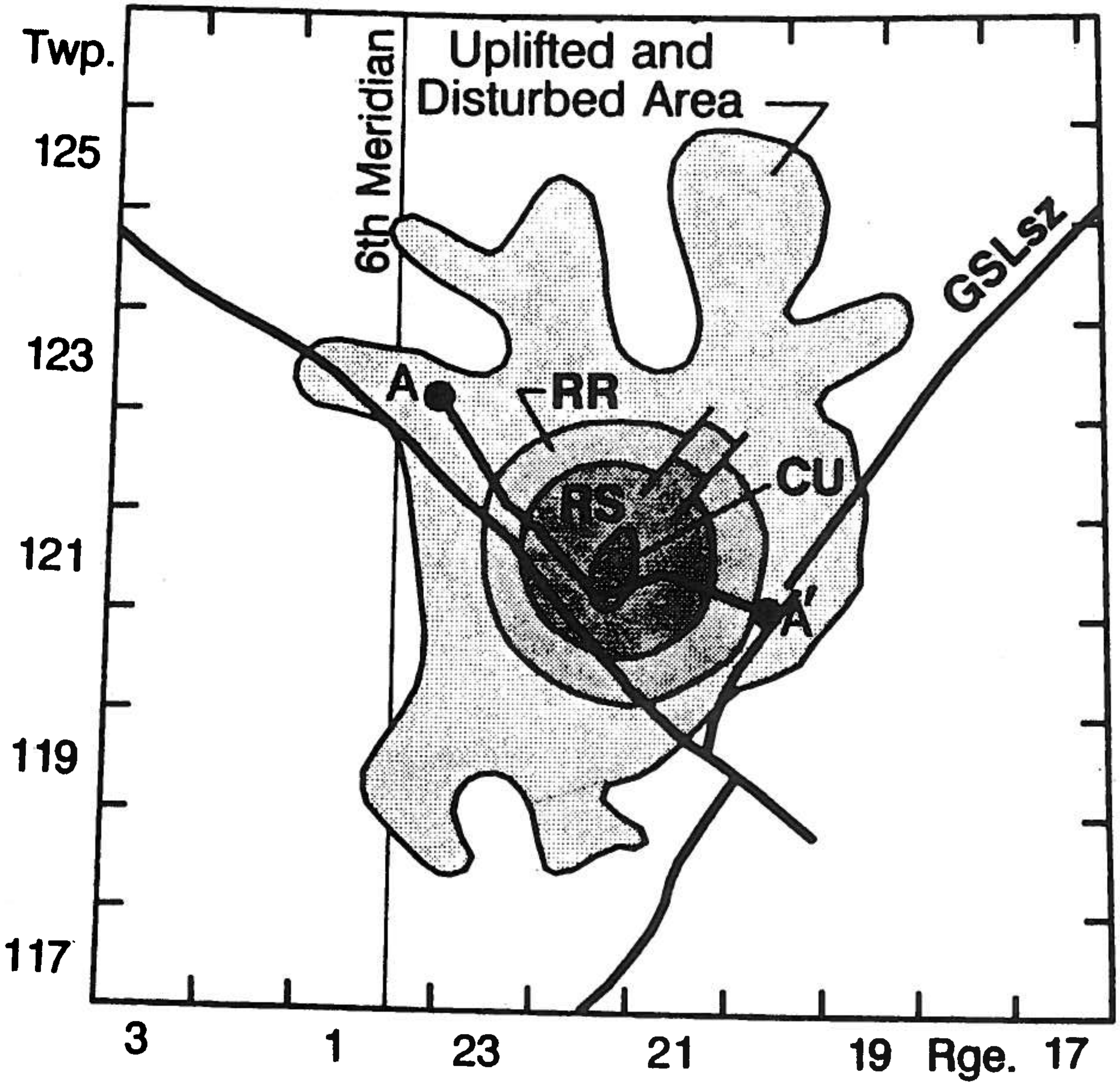
FIGURE 2



Steen River Structure

Main Tectonic Elements

RS	Rim Syncline
CU	Central Uplift
RR	Raised Rim
GSLsz	Great Slave Lake shear zone

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FIGURE 3

Erosion and Burial

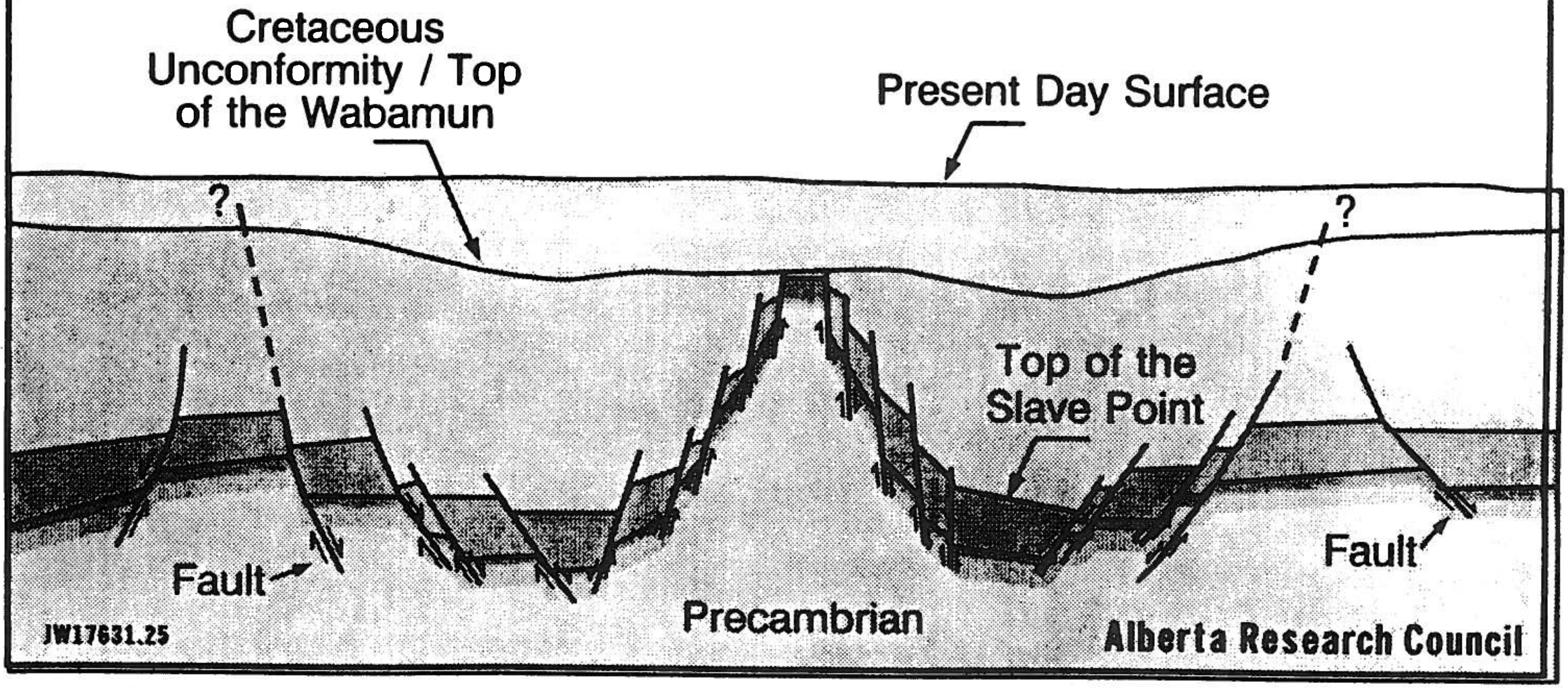

FIGURE 4

of middle and late Devonian carbonates, evaporites and shales (Figure 5). These are truncated by the pre-Cretaceous unconformity which is normally found at the top of the Wabamun Formation. Overlying the Devonian are mid-Cretaceous marine shales and recent glacial sediments. There is a suggestion in some company files that Mississippian sediments may be present within the rim syncline of the SRS. The age of the SRS is approximately 95 My, which may place the impact event after the commencement of deposition of the Cretaceous marine shales.

Structure maps of the basement and pre-Cretaceous unconformity show the outline of the SRS (Figures 6 and 7). Isopach maps for slices within the Devonian succession show no evidence of the impact structure (Figure 8).

HYDROCARBON POTENTIAL

The SRS lies within 40 km of the important Zama oil and gas field. Several smaller fields occur close by (e.g. the Dizzy field located against the Great Slave Lake shear zone), and there are oil and gas shows within the structure itself. The recognized hydrocarbon potential of the SRS must, therefore, be taken into account in any study.

Existing data on the area around the SRS will provide a good base for a drilling program. The acquisition of seismic, aeromagnetic and gravity data will be a priority in the early project stages. Downhole logs of the existing exploration holes in the area will compliment the geophysical data and aid in defining drill locations. Unfortunately previous exploration work concentrated only on the narrow zones of economic interest. This means that core of zones which are important to a scientific understanding of the structure (e.g. Cretaceous, Basement and Late Devonian) are missing. In addition, certain areas (e.g. the rim syncline and the central uplift) have been ignored by the explorationists.

However, there are a number of studies which could be included in this proposal which would be of benefit and interest to the oil industry.

1) Studies of the hydrocarbons within the SRS could include identification of potential source rocks and fluid pathways. The timing

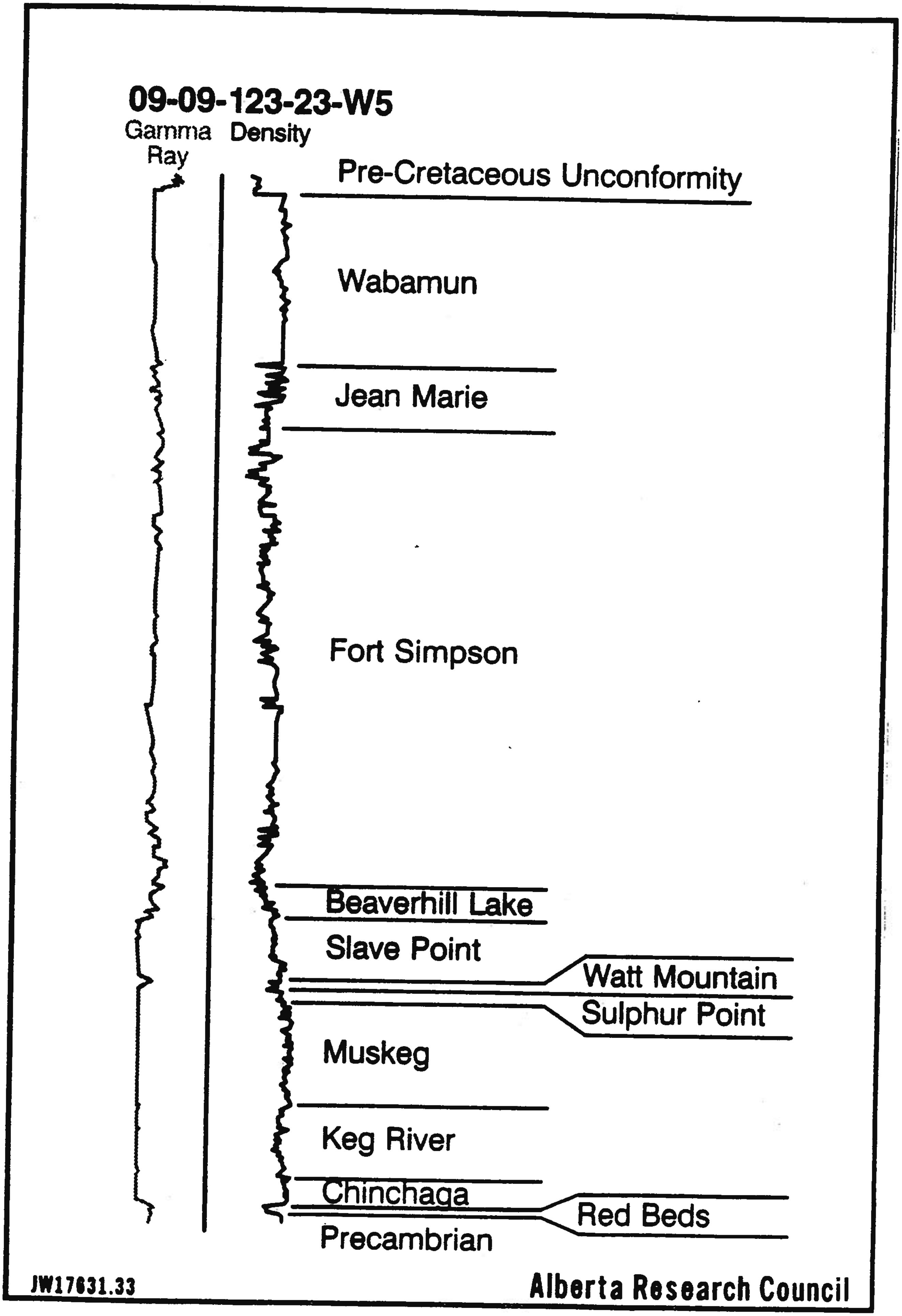
09-09-123-23-W5
Gamma Ray
Density
Pre-Cretaceous Unconformity
Wabamun
Jean Marie
Fort Simpson
Beaverhill Lake
Slave Point
Watt Mountain
Sulphur Point
Muskeg
Keg River
Chinchaga
Red Beds
Precambrian
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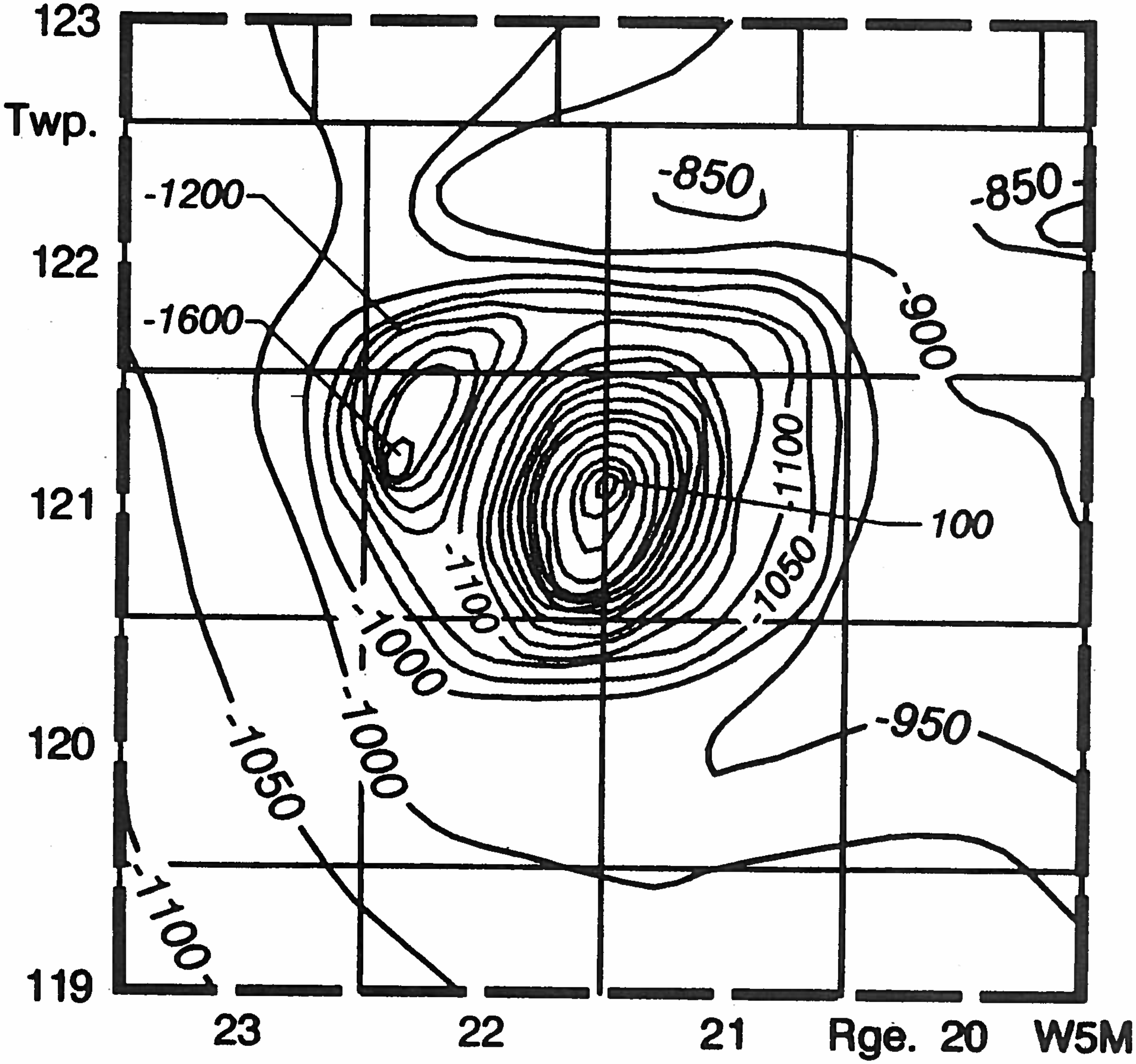
FIGURE 5



Steen River Structure

Structure on the Basement

Detailed
Contour Interval: 100 m

Primary
Contour Interval: 50 m

Datum = Sea Level

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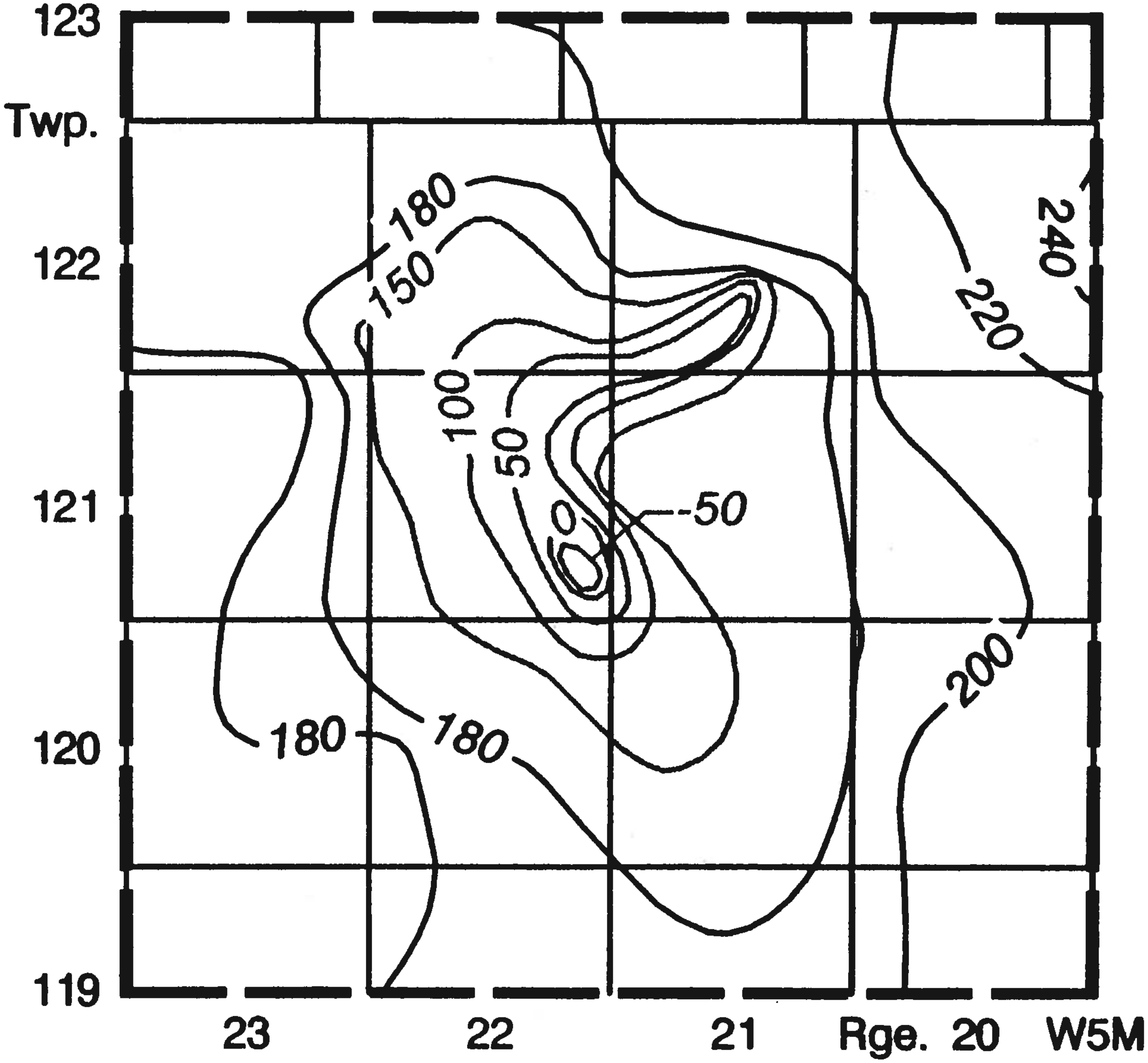
FIGURE 6



Steen River Structure

Structure on the Top of Wabamun

Detailed
Contour Interval: 50 m

Primary
Contour Interval: 20 m

Datum = Sea Level

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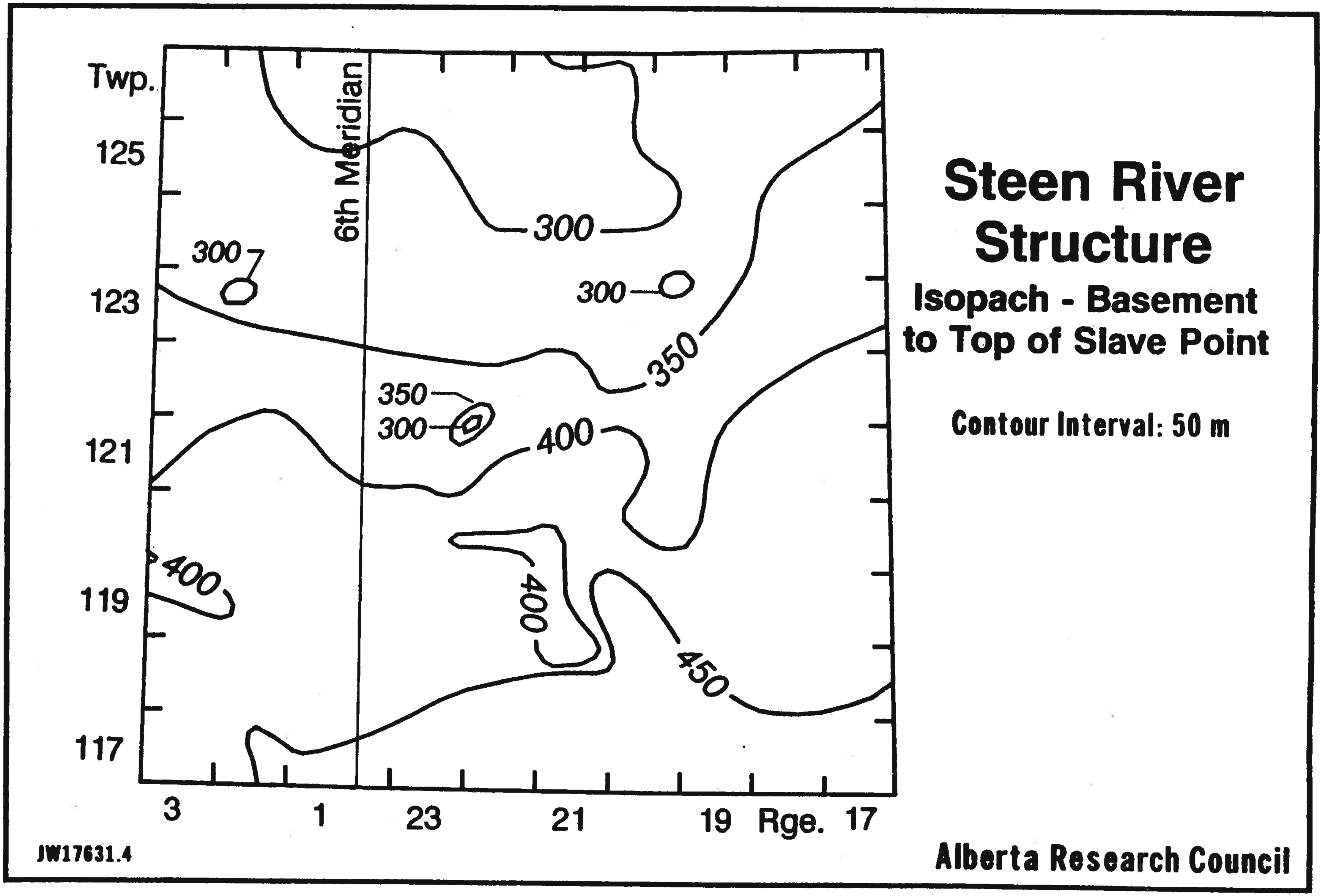
FIGURE 7



Steen River Structure

Isopach - Basement to Top of Slave Point

Contour Interval: 50 m

Alberta Research Council

FIGURE 8

of oil and gas migration through the structure is also important.
2) Reservoir studies could include examination of fracture enhancement, dolomitization and trapping mechanisms.
3) Timing of the impact is crucial in assessing the hydrocarbon potential of the area. In addition, the role of the impact event in triggering local displacement of the regional faults is unknown. Related to this is the role of the Great Slave Lake shear zone as a possible major fluid pathway in the region. An intriguing question is, whether the known, significant hydrocarbon potential of the region is related to tectonic reactivation triggered by the SRS impact.
The above aspects of the study could be carried out as part of a joint venture with industry. Their contribution would be data which would better enable us to define targets for drilling.

OBJECTIVES

1. Determine the nature and tectonic history of the SRS and its role in global and regional climate and environment modification. Compare with Boltysh.
2. Devise a model for SRS type impacting events. Compare with Montagnais.
3. Determine the nature and extent of the melt rocks and breccia.
4. Determine the shape of the central uplift and the rim syncline.
5. Determine the precise age of the SRS, and consequently, whether it represents part of a multiple impact event.
6. Determine whether sediments which are of an age not regionally preserved are present as faulted blocks within the rim syncline.
7. Determine the relationship of the SRS impact event to regional tectonism.
8. Determine the hydrocarbon potential and fluid migration and maturation history of the SRS.
9. Determine the mineral potential of the SRS.
10. Determine the precise age of the overlying Cretaceous sediments.
11. Determine the presence or absence of a temperature anomaly associated with the SRS.
12. Determine, if suitable seismic data exists, the nature of the SRS at

depth within the basement.

WORKPLAN

The SRS proposal is scheduled to run over an eighteen month period, the exact timing to be determined by the necessity for winter drilling. Figure 9 shows the timing of the different activities. These activities are outlined below.

1) Acquire seismic data.

Many kilometres of seismic lines over the SRS are on file in company offices in Calgary. Some of this data is available for sale or as company participation in the SRS project. Examination of this data will provide a good tectonic framework within which to plan a drilling program. In addition to the seismic data, aeromagnetic and gravity data is also available.

2) Interpret seismic data.

Reworking of the older data will provide a wealth of information on the tectonics of the SRS and the region around it. Processing the newer data to a greater depth will provide information on the effects of the impact at depth in the crust.

3) Select drillsites.

Based upon the geophysical work of the first two stages and the existing geological interpretations of the area, drillholes will be tentatively located to derive the maximum amount of information.

4) Inspect/finalize drillhole locations.

Ground checking of the locations for accessibility and suitability for drilling will be carried out. Where possible the holes will be located on previously cleared sites to facilitate rig moves.

5) Field operations.

This will consist of the drilling, coring and geophysical logging of the holes.

6) Core logging.

This will initially be done, along with sampling for petrography and geochemistry, in the field. Core will be removed to the Minerals Core Research Facility in Edmonton for further analysis after the drilling is completed.

FIGURE 9

'STEEN RIVER STRUCTURE' DRILL PROGRAM :

WORK PLAN

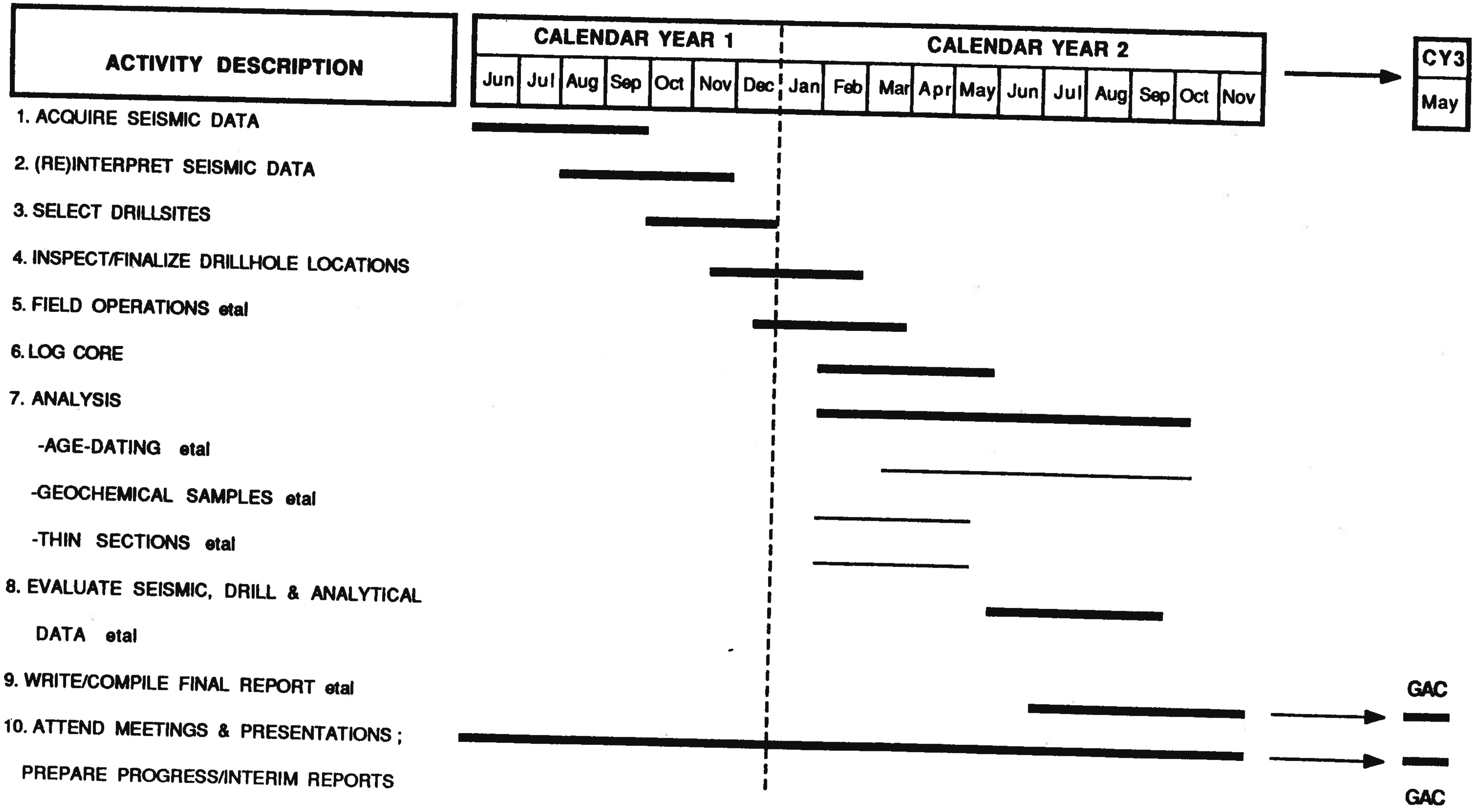


FIGURE 10

'STEEN RIVER STRUCTURE' DRILL PROGRAM : PROPOSED BUDGET

CATEGORY	ITEM	BUDGETED $
MANPOWER	REQUIREMENTS/COSTS .....Associate Research Officer (18 months fulltime) $75/hr x 8hr/d x 20d/mth x 18mth = $216,000 .....Tech2 (18 months fulltime) $53/hr x 8hr/d x 20d/mth x 18mth = $152,640 .....6 Professionals @ 4 man-mth/professional $75/hr x 8hr/d x 20d/mth x 24mth = $288,000 .....6 Tech2's @ 4 man-mth/tech2 $53/hr x 8hr/d x 20d/mth x 24mth = $203,520 .....Clerical staff @ 4 man-mth $32/hr x 8hr/d x 20d/mth x 4mth = $20,480 .....2 Summer Staff @ 4 man-mth/position $32/hr x 8hr/d x 20d/mth x 8mth = $40,960	$921,600
FIELD OPERATIONS	CAMP COSTS .....assume 25 man camp for 60 days @ $1200/d	$72,000
	DRILLING COSTS (1 DDH @ TD : 1500m) .....all-inclusive drilling charges; 1500m @ $150/m = $225,000 .....slim-line logging to 200m; $5,000	$225,000
	DRILLING COSTS (1HOLE @ 2200m & 3 HOLES @ 500m each) .....includes surface prep etal, drilling, mud, surface casing & cement, logging (DIL, FDL & Sonic), supervision & abandonment .....assume 42 drill-days .....assume no delay/slow-down for coring &/or testing	$900,000
	FIELD-TIME TRAVEL EXPENSES (DURING DRILLING OPERATIONS) .....assume 2 persons @ $1000/person	$2,000
	SITE INSPECTION .....assume 8 helicopter-hr @ $645/flight-hr from High Level .....travel expenses for 2 persons for Edmonton-High Level-Edmonton	$6,000
SCIENTIFIC RESEARCH	AGE-DATING	$10,000
	COMPUTING etal	$15,000
	GENERAL SUPPLIES & SERVICES	$15,000
	GEOCHEMICAL ANALYSIS .....assume 100 rock analysis @ $50/analysis .....assume 100 hydrocarbon analysis @ $50/analysis	$10,000

....cont.... FIGURE 10

CATEGORY	ITEM	BUDGETED $
SCIENTIFIC RESEARCH ....continued	SAMPLE PREPARATION .....assume 100 thin sections @ $50/thin section	$5,000
	SEISMIC DATA .....data acquisition; $10,000 .....data (re)interpretation; $10,000	$20,000
REPORTS	MEETINGS, PRESENTATIONS & PUBLIC RELATIONS	$10,000
	REPORT PRESENTATION & REPRODUCTION .....includes editing, drafting & printing	$20,000
CONTINGENCIES	6% OF ABOVE ITEMS	$133,896
	TOTAL :	$2,365,496

7) Analysis.

Samples will be submitted for age dating. Thin section work and interpretation of the geochemical results will be carried by members of the project team.

8) Evaluate seismic, drill and analytical data.

The full spectrum of data obtained in the course of the project will be integrated into a formation model for the SRS.

9) Write/Compile final report.

This part of the workplan will be concerned with pulling together all the components of the project and writing up a report for publication in a suitable medium. Presentation of the data at the GAC annual meeting following the conclusion of the project may be appropriate.

10) Attend meetings and prepare presentations.

This component will be ongoing during the entire project and will involve the preparation of interim reports, presentation of results at appropriate forums and generally keeping the project high profile.

RESEARCH TEAM

The current team are listed with their affiliations as authors of this proposal. Each members expertise is listed below:

John Wilson - Alberta Shield geology-spokesperson
Willem Langenberg - structural geology
Lynn Jeffries and Jeff Tooth - hydrocarbon potential of the SRS
Richard Grieve - impacts and impact modelling
Zoltan Berkes - geophysics

Not all of the team members will be involved throughout the project. The current major gap in team expertise is in the field of geochemistry. This will be filled on a priority basis from within Canada's academic community prior to commencement of the project. Other smaller gaps will be filled as needed on a contract basis.

BUDGET

Figure 10 is an interim budget including all aspects of the proposed work on the SRS. Total funding required amounts to $2,365,496. This figure assumes the use of a drill rig already in the general area of the SRS or Zama, and that geophysical data can be acquired from industry for use in this project. Both these assumptions are reasonable.

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