# GEOCHEMISTRY OF EARLY TO MIDDLE JURASSIC ORGANIC-RICH SHALES, INTERMONTANE BASINS, BRITISH COLUMBIA

**Filippo Ferri[1] and Michael Boddy[1]**

## ABSTRACT

Rock Eval data are presented for Early to Middle Jurassic black clastics belonging to the Spatsizi and Ashcroft formations. Samples of the Spatsizi Formation originated in northern, northeastern and northwestern parts of the Bowser Basin, and include the Joan Lake, western McConnell Creek and Oweegee Dome areas, respectively. Samples of Ashcroft Formation and equivalent strata were taken in the Ashcroft area and in the vicinity of Likely. Several sample transects of the Spatsizi Formation were made in the Joan Lake area and multi-element, ICP-MS analysis were also acquired for the purposes of characterizing the formation.

Spatsizi and Ashcroft formations are, on average, several hundred metres thick. Total organic carbon contents for these rocks ranges up to 6 % and averages 1.7 %. The Abou Member of the Spatsizi formation averages 30 metres in thickness and contains TOC values of approximately 3.6 %. Rock Eval (S2 peak) and vitrinite reflectance data indicates that these rocks are mature to overmature in these areas and have little to no remaining generative potential. Due to the high thermal maturation levels, very little can be said about the type of kerogen this organic matter represented, although considering the marine origin of the sediments it was either Type I or II. Assuming that much of the organic material was expelled during maturation of these sediments, the original organic content of these rocks may have been from 2 to 4 times greater, suggesting they were excellent source rocks.

These Early to Middle Jurassic black clastic rocks are regional in extent, underlying the entire Bowser Basin and potentially many of the other Mesozoic Intermontane clastic sedimentary basins. Under the proper conditions, these rocks would act as an excellent source rock.

*Filippo Ferri and Michael Boddy, Geochemistry of Early to Middle Jurassic Organi-Rich Shales, Intermontane Basins, British Columbia* in Summary of Activities 2005*, BC Ministry of Energy and Mines, pages 132-151.*

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**Keywords:** Source rocks, geochemistry, organic, hydrocarbons, metals, Early Middle Jurassic, Bowser Basin, Spatsizi Formation, Ashcroft Formation, Likely, Oweegee Dome

## INTRODUCTION

During the summer of 2003 several localities containing Early to Middle Jurassic black clastics within the Quesnel Trough and northern Bowser Basin were sampled for hydrocarbon source rock potential. This organic-rich succession underlies many of the Jura-Cretaceous clastic Intermontane basins of the Canadian Cordillera, and under the right conditions, would have acted as a hydrocarbon source rock. A description of the general geology around the sample areas, together with a regional perspective, was detailed in a Summary of Activities article by Ferri *et al.* (2004). At the time of publishing, the samples had not been analyzed and no data was available for insertion into the article. These analyses have now been performed and this rock Eval data is included in the following pages. In addition, Rock Eval data for samples of the Spatsizi Formation from its type area are also presented here. These samples were collected during the 2004 field season as part of the Integrated Petroleum Resource Potential and Geoscience Studies of the Bowser and Sustut Basins program, a partnership between Natural Resources Canada (Geological Survey of Canada), the B.C. Ministry of Energy and Mines (Resource Development and Geoscience Branch) and Simon Fraser University (Department of Earth Sciences). The ultimate aim of this project is a better understanding of the geology and hydrocarbon potential of these large, Intermontane sedimentary basins (Evenchick *et al.*, 2004, 2005; Hayes *et al.*, 2004).

Samples collected in 2003 originated in the Ashcroft, Likely and western parts of the McConnell Creek map areas (*see* Ferri *et al.*, 2004; Figures 1 to 7). The intent of this paper is to make this analytical data available together with new geological and geochemical data for the Spatsizi Formation from the Joan Lake area of northern Bowser Basin and from the north end of the Oweegee Dome structure in western Bowser Lake map area (104A).

## RESULTS

Data for samples from the Joan Lake, McConnell Creek, Oweegee Dome, Ashcroft, and Likely areas are shown in Table 1. The location of the sample sites are shown in Figures 2 to 7. Samples were analyzed with the

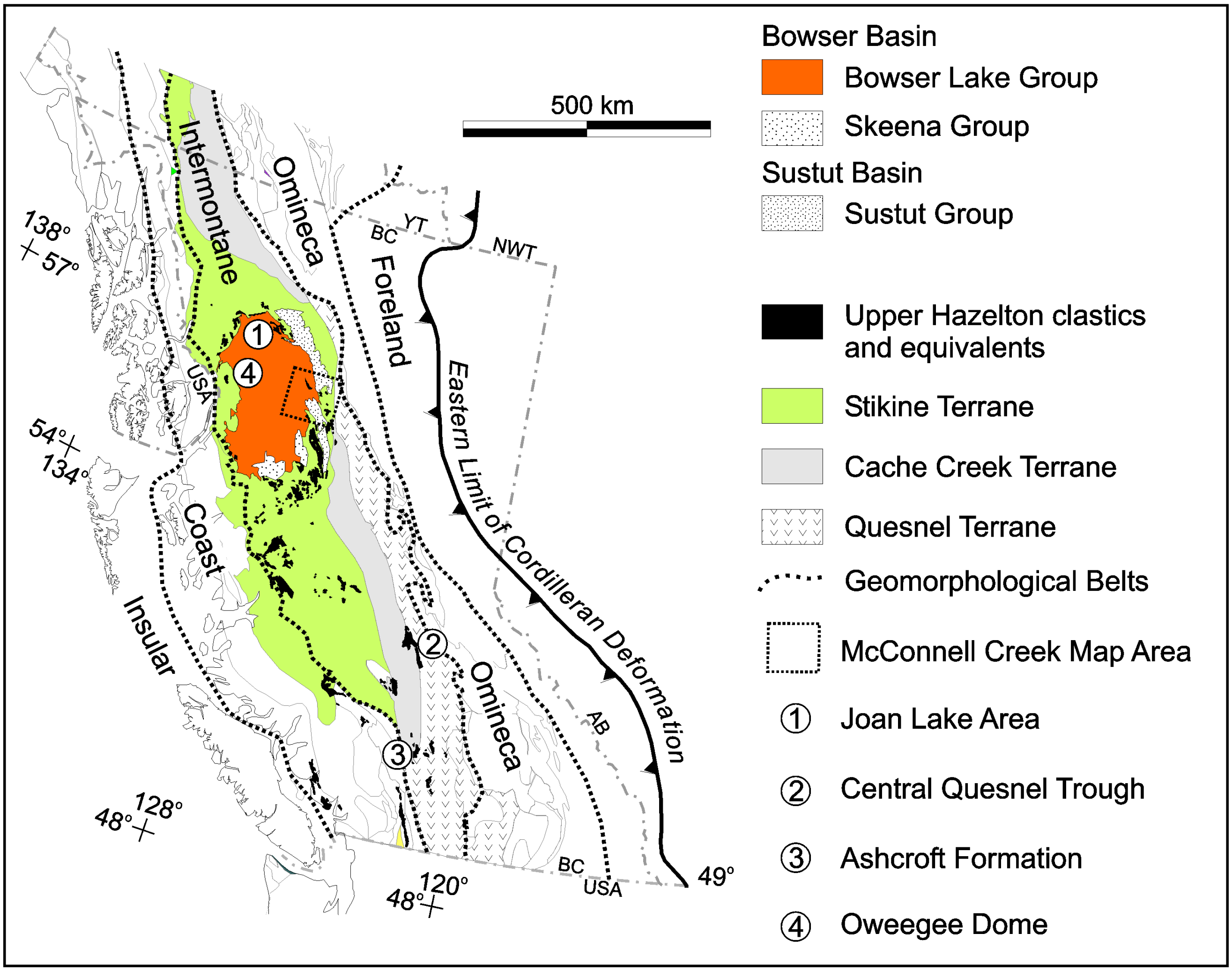

Figure 1. Location of the Bowser and Sustut basins within the geological framework of the Canadian Cordillera (modified from Evenchick *et al.*, 2004).

Rock Eval 6 instrument at the organic petrology laboratories of the Geological Survey of Canada in Calgary. In addition, multi-element ICP-MS analysis of samples from several transects of the Spatsizi Formation in the Joan Lake area were performed via aqua regia and total acid digestion. These analyses were performed at the laboratories of ACME Analytical Ltd. in Vancouver, BC. A description of the analytical technique can be found at the ACME website (www.acmelab.com). The rationale behind these analysis was an attempt at geochemically "finger printing" this sequence via trace metal concentrations. It is commonly understood that many metals are precipitated from seawater due to the reducing environment produced during anoxia. It is hoped that this chemical signature will be useful in future regional correlations of this unit. The aqua regia digestion would primarily dissolve non-silicate material (*i.e.* organics, sulphides, etc.) and give a signature of metals precipitated during deposition. Results from the total acid digestion would reflect, in part, composition of clastic source terranes. Due to budgetary restrictions, only a portion of the samples were analyzed by total acid digestion.

## *Spatsizi Formation*

### *Joan Lake Area*

Along northern Bowser Basin, in the vicinity of Joan Lake, Thomson *et al.* (1986) describe organic-rich shales and siltstones of Pleinsbachian to Bajocian age (Figures 2 to 4). Thomson *et al.* (1986) originally assigned these to the Spatsizi Group, though these were later lowered to formation status by Evenchick and Thorkelson (2005) and made part of the upper Hazelton Group (*see* Ferri *et al.*, 2004).

Fine grained siliciclastic lithologies of the Spatsizi Formation record the termination of widespread volcanic activity, represented by the Hazelton Group, and delineate the beginning of Bowser Basin sedimentation (Ricketts *et al.*, 1992). The Spatsizi Formation can be up to 900 metres thick and is subdivided into 5 units, which are, from oldest to youngest: Joan, Wolf Den, Melisson, Abou and Quock members (Figure 2; Thomson *et al.*, 1986; Evenchick and Thorkelson, 2005). The formation is characterized by dark grey to black, organic-rich, fine

# TABLE 1. ROCK EVAL DATA FOR SAMPLES OF THE SPATSIZI AND ASHCROFT FORMATIONS, TOGETHER WITH UN-NAMED EARLY TO MIDDLE JURASSIC STRATA. UTM COORDINATES IN NAD 27 DATUM.

| Sample Number | Rock Unit | Map Num. | Easting | Northing | Tmax | S1 | S2 | S3 | PI | S2/S3 | PC % | TOC % | HI | OI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| See Figures 2, 3 and 4 for locations | | | | | | | | | | | | | | |
| EPF04-191A | Spatsizi Fm | 191A | 499192 | 6373564 | - | 0.00 | 0.00 | 0.39 | 0.00 | 0.00 | 0.00 | 1.12 | 0 | 35 |
| EPF04-191B | Spatsizi Fm | 191B | 499192 | 6373564 | 518 | 0.00 | 0.00 | 1.17 | 0.00 | 0.00 | 0.00 | 1.91 | 0 | 61 |
| EPF04-191C | Spatsizi Fm | 191C | 499192 | 6373564 | 515 | 0.00 | 0.00 | 0.76 | 0.00 | 0.00 | 0.00 | 1.86 | 0 | 41 |
| EPF04-192A | Spatsizi Fm | 192A | 499147 | 6373447 | - | 0.00 | 0.00 | 0.30 | 0.00 | 0.00 | 0.00 | 1.39 | 0 | 22 |
| EPF04-192B | Spatsizi Fm | 192B | 499147 | 6373447 | - | 0.00 | 0.00 | 0.22 | 1.00 | 0.00 | 0.00 | 1.87 | 0 | 12 |
| EPF04-192C | Spatsizi Fm | 192C | 499147 | 6373447 | - | 0.00 | 0.00 | 0.22 | 1.00 | 0.00 | 0.00 | 1.28 | 0 | 17 |
| EPF04-192D | Spatsizi Fm | 192D | 499147 | 6373447 | - | 0.00 | 0.00 | 0.34 | 1.00 | 0.00 | 0.01 | 1.50 | 0 | 23 |
| EPF04-193A | Spatsizi Fm | 193A | 499122 | 6373305 | 295 | 0.00 | 0.00 | 0.66 | 0.50 | 0.00 | 0.00 | 1.40 | 0 | 47 |
| EPF04-193B | Spatsizi Fm | 193B | 499122 | 6373305 | - | 0.00 | 0.00 | 0.58 | 1.00 | 0.00 | 0.00 | 2.42 | 0 | 24 |
| EPF04-194A | Spatsizi Fm | 194A | 499107 | 6373190 | - | 0.00 | 0.00 | 0.42 | 1.00 | 0.00 | 0.00 | 1.25 | 0 | 34 |
| EPF04-194B | Spatsizi Fm | 194B | 499107 | 6373190 | - | 0.00 | 0.00 | 0.35 | 1.00 | 0.00 | 0.01 | 1.28 | 0 | 27 |
| EPF04-195A | Spatsizi Fm | 195A | 499100 | 6373077 | - | 0.00 | 0.00 | 0.45 | 1.00 | 0.00 | 0.00 | 1.42 | 0 | 32 |
| EPF04-195B | Spatsizi Fm | 195B | 499100 | 6373077 | - | 0.00 | 0.00 | 0.49 | 1.00 | 0.00 | 0.00 | 1.06 | 0 | 46 |
| EPF04-195C | Spatsizi Fm | 195C | 499100 | 6373077 | - | 0.00 | 0.00 | 0.49 | 1.00 | 0.00 | 0.00 | 1.12 | 0 | 44 |
| EPF04-195D | Spatsizi Fm | 195D | 499100 | 6373077 | - | 0.00 | 0.00 | 0.28 | 1.00 | 0.00 | 0.00 | 0.76 | 0 | 37 |
| EPF04-196A | Spatsizi Fm | 196A | 499110 | 6372927 | - | 0.00 | 0.00 | 0.21 | 0.00 | 0.00 | 0.00 | 0.82 | 0 | 26 |
| EPF04-196B | Spatsizi Fm | 196B | 499110 | 6372927 | - | 0.00 | 0.00 | 0.43 | 1.00 | 0.00 | 0.00 | 1.09 | 0 | 39 |
| EPF04-197A | Spatsizi Fm | 197A | 499137 | 6372870 | 337 | 0.00 | 0.00 | 0.42 | 0.53 | 0.00 | 0.00 | 0.90 | 0 | 47 |
| EPF04-197B | Spatsizi Fm | 197B | 499137 | 6372870 | 433 | 0.00 | 0.00 | 0.15 | 0.04 | 0.00 | 0.00 | 0.41 | 0 | 37 |
| EPF04-197C | Spatsizi Fm | 197C | 499137 | 6372870 | - | 0.00 | 0.00 | 0.54 | 1.00 | 0.00 | 0.01 | 1.41 | 0 | 38 |
| EPF04-198A | Spatsizi Fm | 198A | 499130 | 6372737 | - | 0.00 | 0.00 | 0.42 | 1.00 | 0.00 | 0.00 | 1.84 | 0 | 23 |
| EPF04-198B | Spatsizi Fm | 198B | 499130 | 6372737 | - | 0.00 | 0.00 | 0.30 | 1.00 | 0.00 | 0.00 | 2.62 | 0 | 11 |
| EPF04-198C | Spatsizi Fm | 198C | 499130 | 6372737 | 527 | 0.00 | 0.00 | 1.51 | 0.00 | 0.00 | 0.01 | 3.03 | 0 | 50 |
| EPF04-198D | Spatsizi Fm | 198D | 499130 | 6372737 | 517 | 0.00 | 0.01 | 2.18 | 0.06 | 0.00 | 0.01 | 4.60 | 0 | 47 |
| EPF04-199A | Spatsizi Fm | 199A | 499472 | 6372793 | 391 | 0.00 | 0.01 | 1.25 | 0.05 | 0.01 | 0.01 | 0.55 | 2 | 227 |
| EPF04-200A | Spatsizi Fm | 200A | 500666 | 6373358 | 426 | 0.00 | 0.00 | 0.34 | 0.19 | 0.00 | 0.00 | 0.71 | 0 | 48 |
| EPF04-200B | Spatsizi Fm | 200B | 500666 | 6373358 | 587 | 0.00 | 0.00 | 0.44 | 0.91 | 0.00 | 0.00 | 0.24 | 0 | 183 |
| EPF04-201B | Spatsizi Fm | 201B | 500625 | 6373340 | 345 | 0.00 | 0.00 | 0.40 | 0.57 | 0.00 | 0.00 | 1.01 | 0 | 40 |
| EPF04-201C | Spatsizi Fm | 201C | 500625 | 6373340 | 322 | 0.00 | 0.00 | 0.34 | 0.88 | 0.00 | 0.00 | 0.79 | 0 | 43 |
| EPF04-201D | Spatsizi Fm | 201D | 500625 | 6373340 | 522 | 0.00 | 0.00 | 0.88 | 0.86 | 0.00 | 0.00 | 1.18 | 0 | 75 |
| EPF04-202A | Spatsizi Fm | 202A | 500586 | 6373235 | 352 | 0.00 | 0.00 | 1.04 | 0.21 | 0.00 | 0.01 | 0.99 | 0 | 105 |
| EPF04-202B | Spatsizi Fm | 202B | 500586 | 6373235 | 420 | 0.00 | 0.00 | 0.46 | 0.72 | 0.00 | 0.00 | 0.76 | 0 | 61 |
| EPF04-202C | Spatsizi Fm | 202C | 500586 | 6373235 | - | 0.00 | 0.00 | 0.37 | 1.00 | 0.00 | 0.01 | 1.02 | 0 | 36 |
| EPF04-202D | Spatsizi Fm | 202D | 500586 | 6373235 | 362 | 0.00 | 0.00 | 0.59 | 0.47 | 0.00 | 0.00 | 1.27 | 0 | 46 |
| EPF04-203A | Spatsizi Fm | 203A | 500527 | 6373166 | - | 0.00 | 0.00 | 0.51 | 1.00 | 0.00 | 0.00 | 1.16 | 0 | 44 |
| EPF04-203B | Spatsizi Fm | 203B | 500527 | 6373166 | - | 0.00 | 0.00 | 0.46 | 1.00 | 0.00 | 0.01 | 1.19 | 0 | 39 |
| EPF04-203C | Spatsizi Fm | 203C | 500527 | 6373166 | 522 | 0.00 | 0.00 | 1.04 | 0.16 | 0.00 | 0.00 | 1.28 | 0 | 81 |
| EPF04-203D | Spatsizi Fm | 203D | 500527 | 6373166 | 329 | 0.00 | 0.00 | 0.65 | 0.44 | 0.00 | 0.00 | 1.12 | 0 | 58 |
| EPF04-204A | Spatsizi Fm | 204A | 500472 | 6373038 | - | 0.00 | 0.00 | 0.57 | 1.00 | 0.00 | 0.00 | 1.26 | 0 | 45 |
| EPF04-205A | Spatsizi Fm | 205A | 500364 | 6372621 | 606 | 0.00 | 0.00 | 0.74 | 0.23 | 0.00 | 0.00 | 4.92 | 0 | 15 |
| EPF04-205C | Spatsizi Fm | 205C | 500364 | 6372621 | 602 | 0.00 | 0.00 | 0.36 | 0.81 | 0.00 | 0.01 | 4.20 | 0 | 9 |
| EPF04-205D | Spatsizi Fm | 205D | 500364 | 6372621 | 607 | 0.00 | 0.00 | 0.45 | 0.87 | 0.00 | 0.00 | 4.62 | 0 | 10 |
| EPF04-205E | Spatsizi Fm | 205E | 500364 | 6372621 | 519 | 0.00 | 0.01 | 1.72 | 0.01 | 0.01 | 0.01 | 3.65 | 0 | 47 |
| EPF04-206A | Spatsizi Fm | 206A | 500291 | 6372595 | 314 | 0.00 | 0.00 | 0.78 | 0.84 | 0.00 | 0.00 | 4.78 | 0 | 16 |
| EPF04-207A | Spatsizi Fm | 207A | 500253 | 6372571 | 605 | 0.00 | 0.00 | 1.23 | 0.09 | 0.00 | 0.00 | 4.40 | 0 | 28 |
| EPF04-207C | Spatsizi Fm | 207C | 500253 | 6372571 | - | 0.00 | 0.00 | 0.38 | 1.00 | 0.00 | 0.01 | 3.72 | 0 | 10 |
| EPF04-207E | Spatsizi Fm | 207E | 500253 | 6372571 | - | 0.00 | 0.00 | 0.64 | 1.00 | 0.00 | 0.00 | 4.03 | 0 | 16 |
| EPF04-208A | Spatsizi Fm | 208A | 500189 | 6372496 | 522 | 0.00 | 0.02 | 2.45 | 0.16 | 0.01 | 0.01 | 2.88 | 1 | 85 |
| EPF04-209A | Spatsizi Fm | 209A | 500068 | 6372471 | 524 | 0.00 | 0.01 | 1.70 | 0.00 | 0.01 | 0.01 | 1.74 | 1 | 98 |
| EPF04-210A | Spatsizi Fm | 210A | 499972 | 6372463 | 572 | 0.00 | 0.00 | 1.03 | 0.04 | 0.00 | 0.00 | 3.45 | 0 | 30 |
| EPF04-257B | Spatsizi Fm | OD | 460587 | 6283817 | - | 0.00 | 0.00 | 0.23 | 1.00 | 0.00 | 0.00 | 0.38 | 0 | 61 |
| EPF04-258A | Spatsizi Fm | OD | 460562 | 6283813 | - | 0.00 | 0.00 | 0.27 | 1.00 | 0.00 | 0.00 | 0.23 | 0 | 117 |
| EPF04-259A | Spatsizi Fm | OD | 460540 | 6283886 | 606 | 0.00 | 0.00 | 0.70 | 0.00 | 0.00 | 0.00 | 1.47 | 0 | 48 |
| EPF04-260A | Spatsizi Fm | OD | 460529 | 6283956 | 606 | 0.00 | 0.01 | 0.18 | 0.03 | 0.06 | 0.01 | 1.69 | 1 | 11 |
| EPF04-261A | Spatsizi Fm | OD | 460489 | 6284094 | 521 | 0.00 | 0.01 | 0.44 | 0.00 | 0.02 | 0.01 | 0.87 | 1 | 51 |

## TABLE 1, CONTINUED

| Sample Number | Rock Unit | Map Num. | Easting | Northing | Tmax | S1 | S2 | S3 | PI | S2/S3 | PC % | TOC % | HI | OI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| See Figure 5 for locations | | | | | | | | | | | | | | |
| EPF03-091-1 | Bowser Lk Gp | 1 | 599419 | 6273768 | - | 0.00 | 0.00 | 0.44 | 1.00 | 0.00 | 0.00 | 0.57 | 0 | 77 |
| EPF03-095-1 | Spatsizi Fm | 2 | 617036 | 6223010 | 441 | 0.00 | 0.12 | 0.51 | 0.01 | 0.24 | 0.02 | 1.58 | 8 | 32 |
| EPF03-135-1 | Spatsizi Fm | 3 | 605196 | 6285736 | 606 | 0.00 | 0.00 | 0.43 | 0.60 | 0.00 | 0.01 | 1.75 | 0 | 25 |
| EPF03-139-1 | Spatsizi Fm | 4 | 604749 | 6286114 | 525 | 0.00 | 0.05 | 1.06 | 0.00 | 0.05 | 0.01 | 1.57 | 3 | 68 |
| EPF03-139-3 | Spatsizi Fm | 4 | 604749 | 6286114 | 440 | 0.01 | 0.03 | 1.03 | 0.18 | 0.03 | 0.01 | 1.11 | 3 | 93 |
| EPF03-139-4 | Spatsizi Fm | 4 | 604749 | 6286114 | 531 | 0.00 | 0.01 | 0.74 | 0.38 | 0.01 | 0.00 | 1.49 | 1 | 50 |
| EPF03-140-1 | Spatsizi Fm | 5 | 604661 | 6286652 | 600 | 0.00 | 0.00 | 0.65 | 0.12 | 0.00 | 0.01 | 1.39 | 0 | 47 |
| EPF03-142-1 | Spatsizi Fm | 6 | 604317 | 6287363 | 295 | 0.00 | 0.00 | 1.27 | 0.54 | 0.00 | 0.01 | 3.12 | 0 | 41 |
| EPF03-161-1 | Spatsizi Fm | 7 | 600946 | 6286619 | - | 0.00 | 0.00 | 0.33 | 1.00 | 0.00 | 0.00 | 0.81 | 0 | 41 |
| EPF03-165-1 | Spatsizi Fm | 8 | 601148 | 6285998 | - | 0.00 | 0.00 | 0.20 | 1.00 | 0.00 | 0.00 | 0.59 | 0 | 34 |
| EPF03-166-1 | Spatsizi Fm | 9 | 601192 | 6285337 | 606 | 0.00 | 0.00 | 1.11 | 0.42 | 0.00 | 0.01 | 3.87 | 0 | 29 |
| EPF03-167-3 | Spatsizi Fm | 10 | 608444 | 6292880 | 604 | 0.00 | 0.00 | 0.34 | 0.32 | 0.00 | 0.00 | 0.62 | 0 | 55 |
| EPF03-168-1 | Spatsizi Fm | 11 | 608257 | 6292354 | 606 | 0.00 | 0.01 | 0.38 | 0.03 | 0.03 | 0.00 | 1.15 | 1 | 33 |
| EPF03-171-1 | Spatsizi Fm | 12 | 608301 | 6291561 | 607 | 0.00 | 0.03 | 0.27 | 0.00 | 0.11 | 0.00 | 0.86 | 5 | 31 |
| EPF03-173-1 | Spatsizi Fm | 13 | 608915 | 6291068 | 605 | 0.00 | 0.02 | 0.32 | 0.00 | 0.06 | 0.00 | 0.93 | 2 | 34 |
| EPF03-177-1 | Spatsizi Fm | 14 | 608594 | 6289218 | 606 | 0.00 | 0.00 | 0.43 | 0.33 | 0.00 | 0.00 | 0.66 | 0 | 65 |
| EPF03-180-3 | Spatsizi Fm | 15 | 598939 | 6293063 | - | 0.00 | 0.00 | 1.87 | 1.00 | 0.00 | 0.01 | 6.01 | 0 | 31 |
| EPF03-184-1 | Spatsizi Fm | 16 | 598577 | 6292977 | 446 | 0.00 | 0.01 | 0.96 | 0.02 | 0.01 | 0.01 | 1.37 | 1 | 70 |
| EPF03-184-2 | Spatsizi Fm | 16 | 598577 | 6292977 | - | 0.00 | 0.00 | 0.56 | 0.97 | 0.00 | 0.00 | 2.23 | 0 | 25 |
| EPF03-191-1 | Spatsizi Fm | 17 | 605103 | 6285081 | 539 | 0.00 | 0.04 | 0.07 | 0.00 | 0.57 | 0.00 | 0.27 | 15 | 26 |
| EPF03-205-1 | Spatsizi Fm | 18 | 607857 | 6279674 | 605 | 0.00 | 0.02 | 0.27 | 0.01 | 0.07 | 0.01 | 0.91 | 2 | 30 |
| EPF03-224-2 | Spatsizi Fm | 19 | 648880 | 6247807 | 469 | 0.01 | 0.04 | 0.69 | 0.21 | 0.06 | 0.02 | 0.18 | 22 | 383 |
| EPF03-228-1 | Spatsizi Fm | 20 | 596444 | 6298903 | 382 | 0.00 | 0.02 | 1.47 | 0.13 | 0.01 | 0.04 | 1.04 | 2 | 141 |
| EPF03-231-1 | Spatsizi Fm | 21 | 595830 | 6297891 | 315 | 0.01 | 0.00 | 0.45 | 0.96 | 0.00 | 0.00 | 3.34 | 0 | 13 |
| See Figure 7 for locations | | | | | | | | | | | | | | |
| FF04-01A | Ashcroft Fm | B | 619543 | 5613654 | 606 | 0.00 | 0.00 | 0.28 | 0.16 | 0.00 | 0.00 | 1.10 | 0 | 25 |
| FF04-01B | Ashcroft Fm | B | 619543 | 5613654 | - | 0.00 | 0.00 | 0.15 | 1.00 | 0.00 | 0.00 | 0.60 | 0 | 25 |
| FF04-01E | Ashcroft Fm | B | 619543 | 5613654 | 606 | 0.00 | 0.01 | 1.21 | 0.11 | 0.01 | 0.01 | 5.09 | 0 | 24 |
| FF-03-1A | Ashcroft Fm | A | 621033 | 5620414 | 475 | 0.00 | 0.04 | 0.43 | 0.00 | 0.09 | 0.01 | 1.32 | 3 | 33 |
| FF-03-2A | Ashcroft Fm | A | 621066 | 5620479 | - | 0.00 | 0.00 | 0.36 | 1.00 | 0.00 | 0.00 | 1.58 | 0 | 23 |
| FF-03-2B | Ashcroft Fm | A | 621066 | 5620479 | 315 | 0.00 | 0.00 | 0.24 | 0.91 | 0.00 | 0.00 | 1.17 | 0 | 21 |
| FF-03-3A | Ashcroft Fm | A | 621073 | 5620505 | 490 | 0.00 | 0.00 | 3.95 | 1.00 | 0.00 | 0.01 | 0.73 | 0 | 541 |
| FF-03-4A | Ashcroft Fm | A | 621106 | 5620590 | - | 0.00 | 0.00 | 1.90 | 1.00 | 0.00 | 0.00 | 1.65 | 0 | 115 |
| FF-03-4B | Ashcroft Fm | A | 621106 | 5620590 | 606 | 0.00 | 0.00 | 1.16 | 1.00 | 0.00 | 0.00 | 1.42 | 0 | 82 |
| FF-03-5A | Ashcroft Fm | A | 621140 | 5620636 | - | 0.00 | 0.00 | 1.30 | 1.00 | 0.00 | 0.00 | 0.73 | 0 | 178 |
| FF-03-6A | Ashcroft Fm | A | 621147 | 5620691 | 607 | 0.00 | 0.00 | 1.01 | 1.00 | 0.00 | 0.00 | 2.85 | 0 | 35 |
| FF-03-8A | Ashcroft Fm | A | 621046 | 5620363 | 324 | 0.00 | 0.00 | 0.55 | 1.00 | 0.00 | 0.01 | 1.29 | 0 | 43 |
| See Figure 6 for locations | | | | | | | | | | | | | | |
| FF-03-13A | E-M Jurassic | C | 589945 | 5833905 | 606 | 0.00 | 0.13 | 0.49 | 0.02 | 0.27 | 0.02 | 5.50 | 3 | 9 |
| FF-03-13B | E-M Jurassic | C | 589945 | 5833905 | 605 | 0.00 | 0.12 | 0.39 | 0.02 | 0.31 | 0.02 | 5.05 | 3 | 8 |

OD - Oweegee Dome

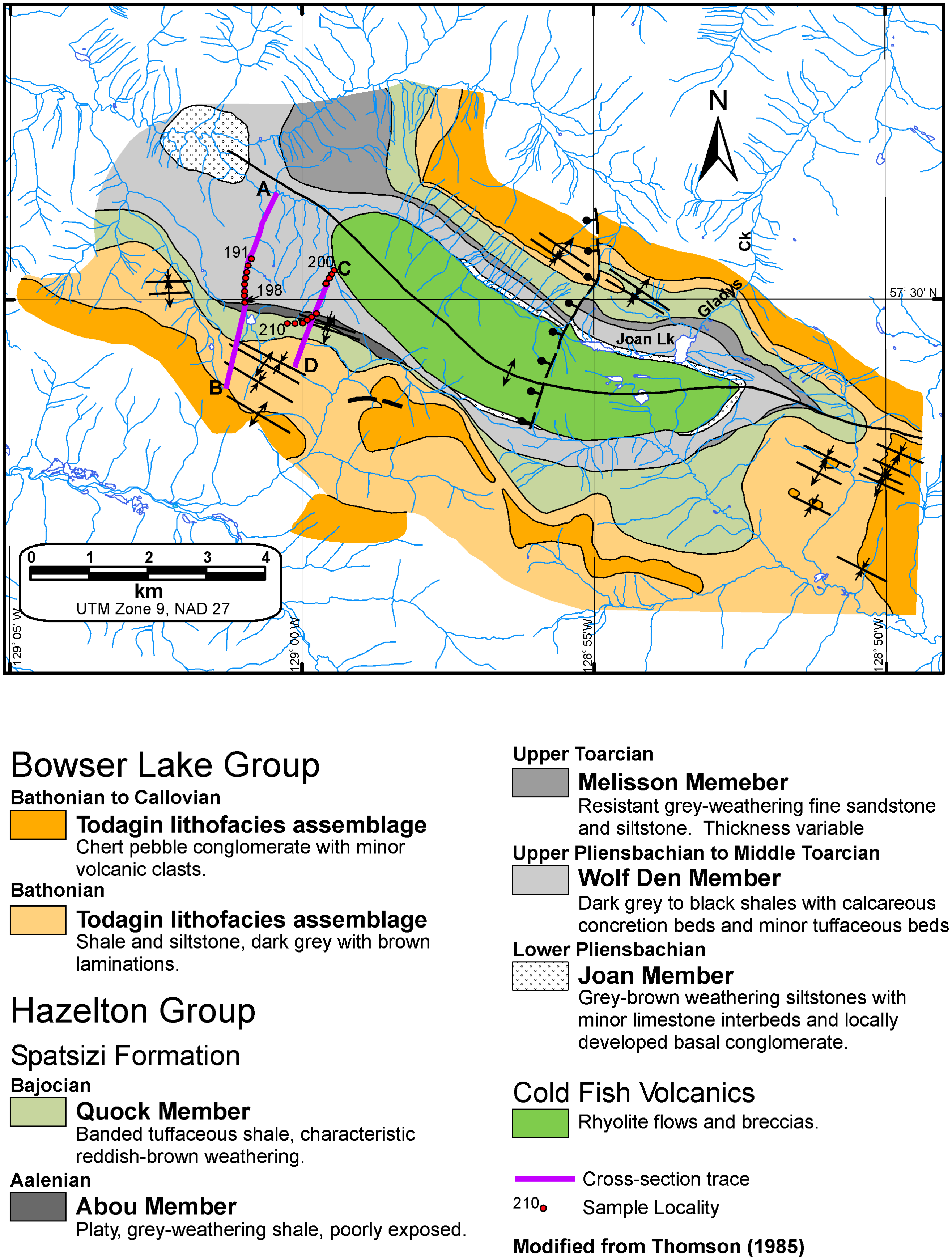

Figure 2. Geological map of the Joan Lake area showing location of sampling transects and structural cross-section lines shown in Figure 3. Adapted from Thomson *et al.*, 1986.

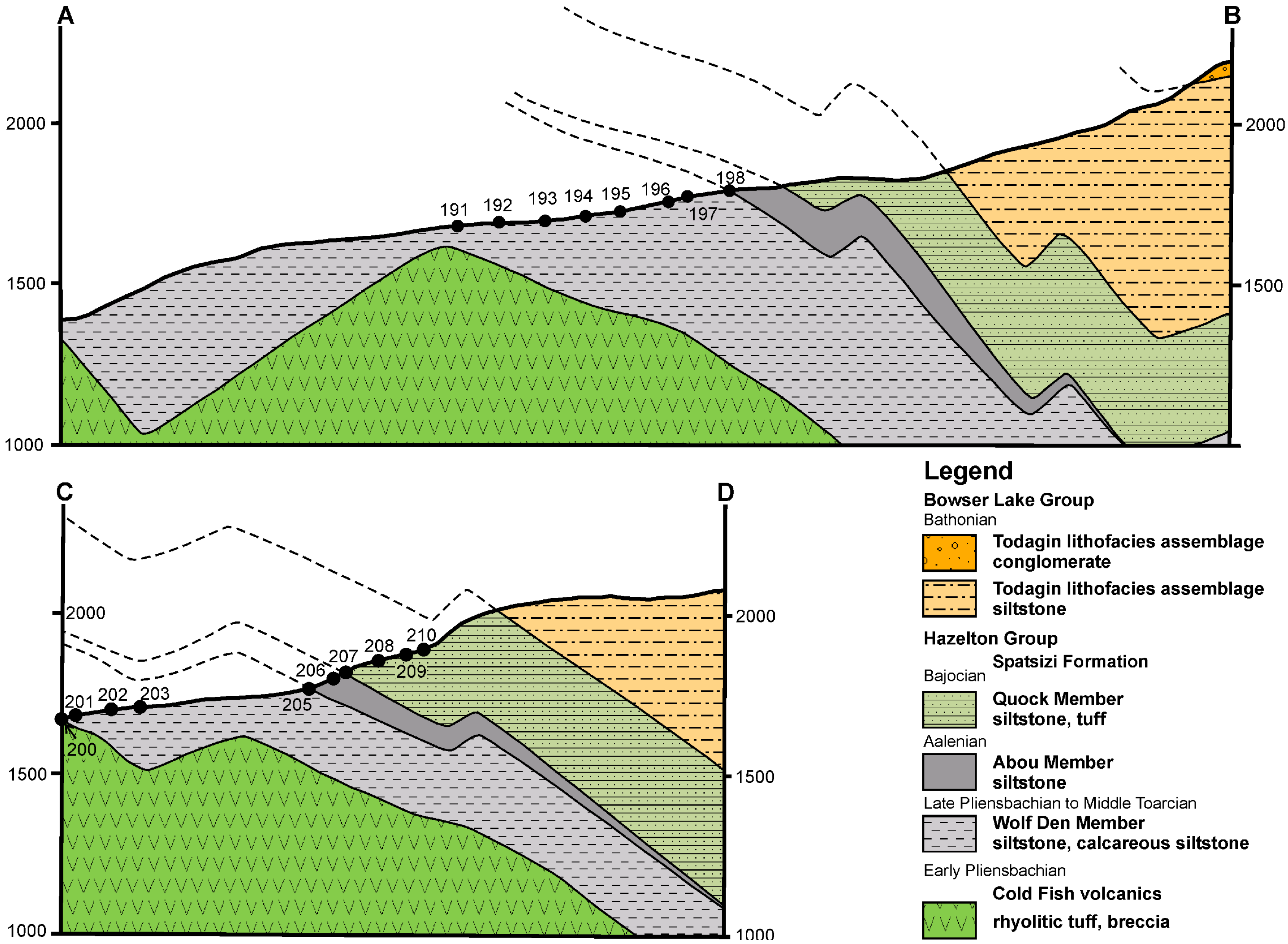

Figure 3. Structural cross-sections along sampling transects in the Joan Lake area. Sample locations refer to data in Tables 1, 2 and 3.

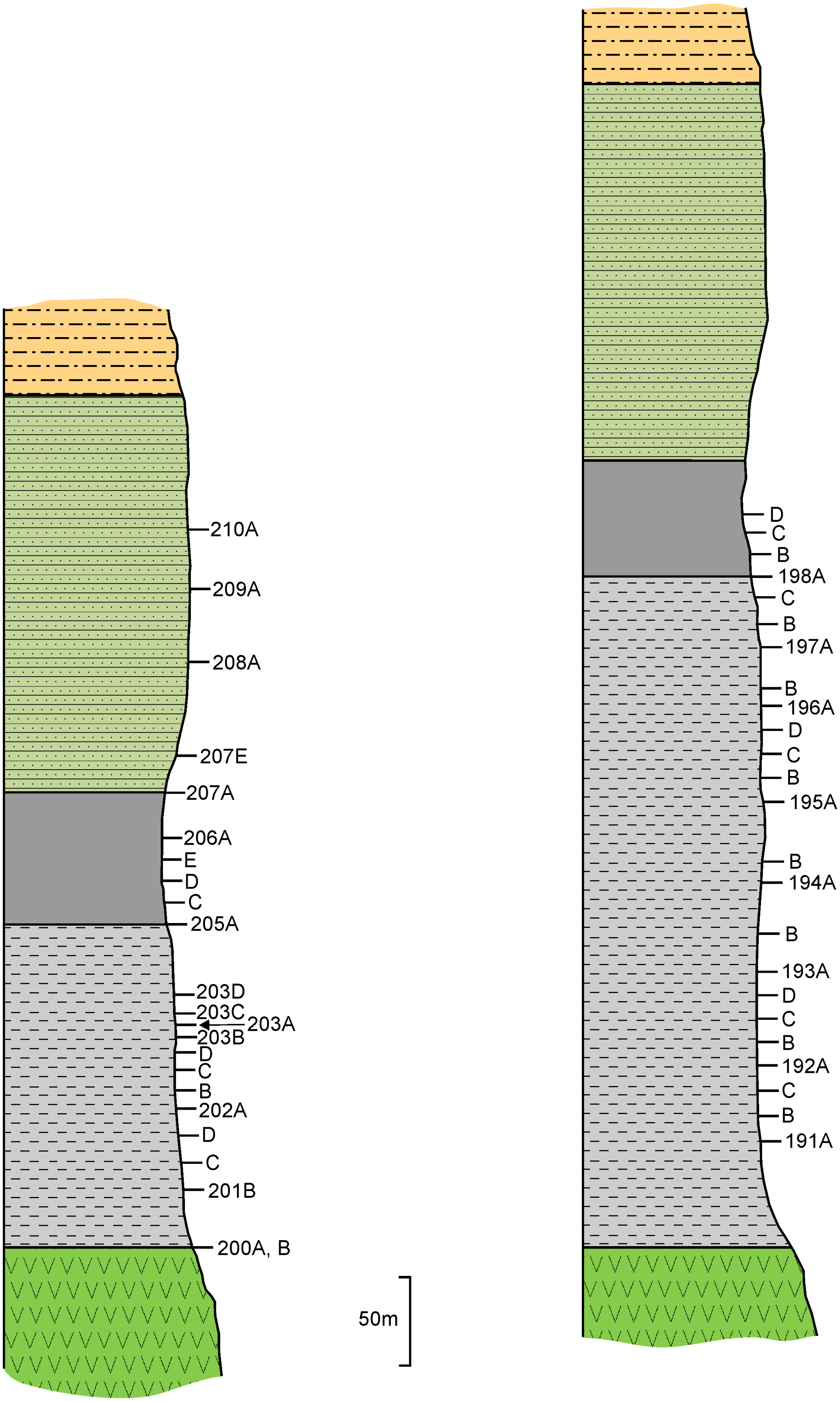

Figure 4. Simplified stratigraphic sections of the Spatsizi Formation as seen along sampling transects. Sample locations refer to data in Tables 1, 2 and 3.

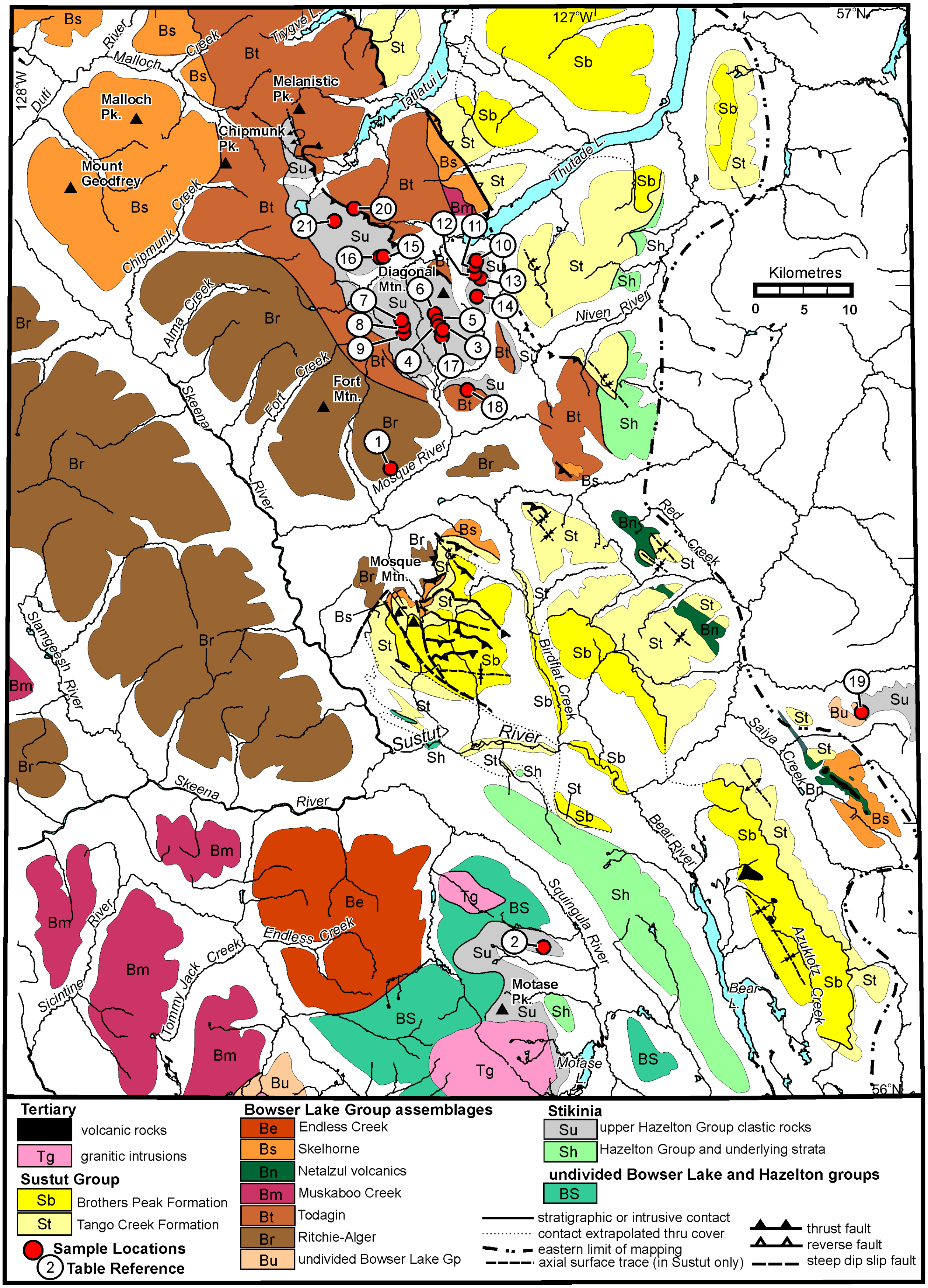

Figure 5. General geology map of the west part of McConnell Creek map area showing the location of Spatsizi Formation samples listed in Table 1. Modified from Evenchick *et al.*, 2004.

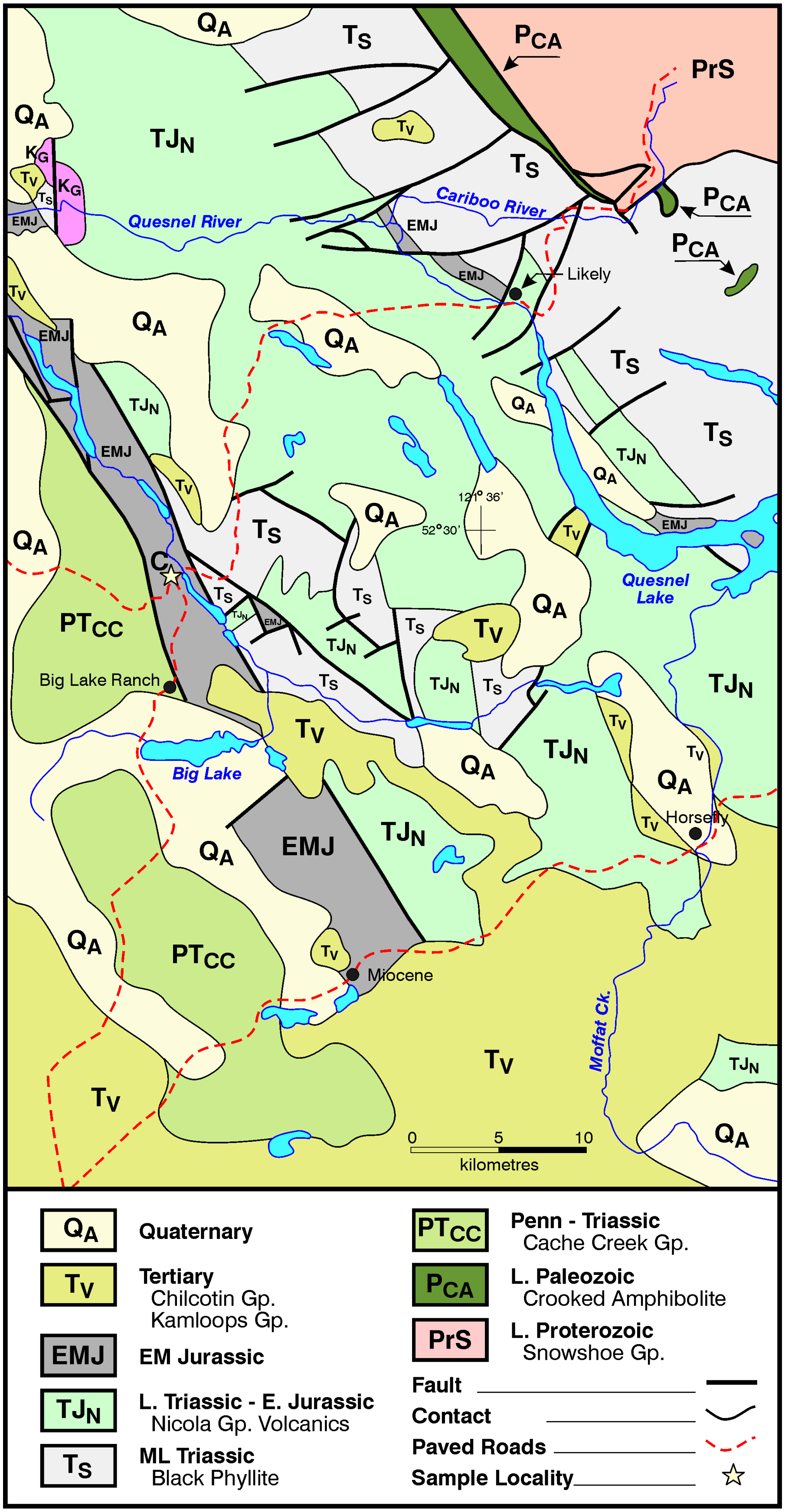

Figure 6. General geology of the Likely area showing the location of un-named Early to Middle Jurassic samples listed in Table 1. Modified from Panteleyev *et al.*, 1996.

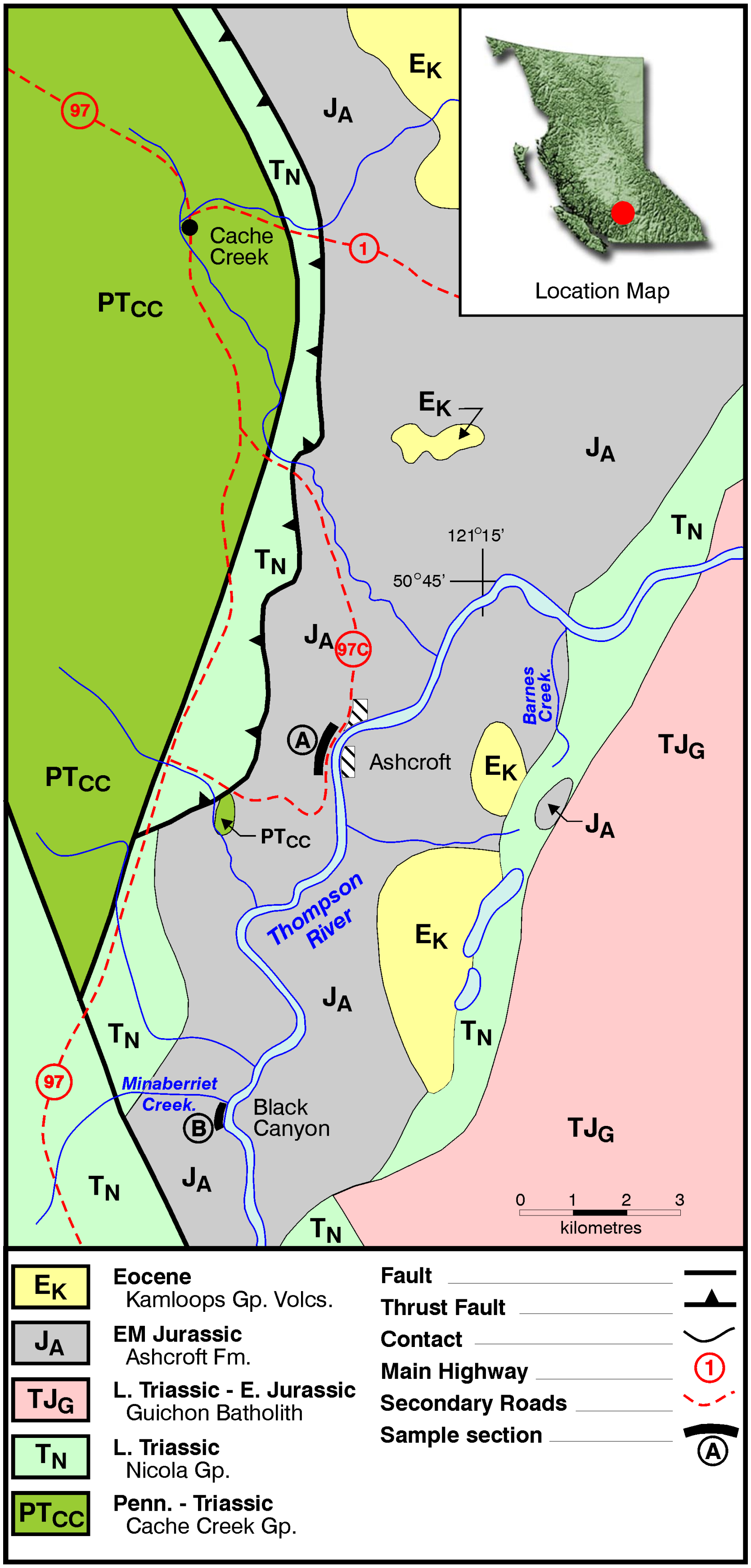

Figure 7. General geology of the Ashcroft area showing the location of Ashcroft Formation samples listed in Table 1. Modified from Travers (1978).

grained siliciclastics which record deposition in anoxic water conditions. The Spatsizi Formation, particularly the upper Abou and Quock members ("Pyjama Beds"), and its equivalents can be traced around the base of the Bowser Basin and found within structural windows, suggesting it underlies the entire basin. The high organic content of Spatsizi shales and siltstones would suggest that, under the proper conditions, this unit may have acted as a hydrocarbon source bed for potential reservoirs in succeeding clastics of the Bowser Lake and Sustut groups.

At Joan Lake, Spatsizi lithologies sit atop rhyolites of the Cold Fish volcanics which are exposed in the core of a doubly plunging anticline. The Spatsizi Formation displays considerable lithologic and thickness variation around this structure. Rocks of the Joan member are only locally developed along the top of the Cold Fish volcanics and the Melisson member is commonly absent due to removal or non-deposition below the sub-Abou unconformity. In the vicinity of Joan Lake, the Spatsizi Formation varies in thickness from 400 to over 900 metres. Although the increased thickness seen at the northwest end of the anticline may in part be structural, cross-sections indicate that the variation is probably a reflection of removal or non-deposition of lithologies below the Abou member (see sections in Figure 3).

The Joan Member is Pliensbachian in age and composed of dark siltstone, mudstone, limestone and locally a thin basal conglomerate. This unit is not developed everywhere above the Cold Fish volcanics and is missing on the south side of the large anticline. This is succeeded by upper Pliensbachian to middle Toarcian dark grey to black, fissile to slaty shale, siltstone or calcareous siltstone of the Wolf Den Member. Thomson *et al.* (1986) describe tuffaceous beds locally. Bedding is typically developed as colour banding and the rock locally has a slightly fetid odour when broken. Some horizons are characterized by abundant small (5 to 10 mm) bivalves of the genera *Bositra* or *Pseudomytiloides*. This is the thickest and most aerially extensive member of the Spatsizi Formation. These rocks are conformably overlain by middle to upper Toarcian, grey-brown resistive siliceous siltstone to fine sandstone of the Melisson Member. The Melisson Member records shallowing conditions, although interbedded siltstone and shales are dark and organic-rich. Unconformably above this and the Wolf Den Member is the Aalenian Abou Member, a sequence of dark grey to black, organic-rich, siltstone to slightly siliceous siltstone up to 100 metres thick. It is usually well cleaved and platy, although it produces blocky rubble where siliceous. These rocks grade into the succeeding Bajocian Quock Member composed of distinctive dark, rusty weathering, blocky, siliceous siltstone characterized by interbeds of thin to moderate bands of beige, white to pinkish bands of fine to medium grained tuff. Regionally, this member is informally referred to as the "Pyjama Beds" due to its characteristic striped nature. This unit locally contains sections of grey to light grey weathering, dark grey to black, fissile calcareous siltstone up to several metres thick. The contact with the overlying Bowser Lake Group occurs over several metres and Quock siltstones lose their siliceous nature and tuffaceous interbeds, and become brown-grey to grey, crumbly and recessive.

Fine clastic rocks of the Spatsizi Formation are invariably high in organic material. The purpose of this investigation was an attempt at systematically quantifying the amount and nature of this organic material through a series of transects across the formation. Two sections were sampled some 6 and 7.5 kilometres west of Joan Lake where a thick section of Abou shales and siltstones have been delineated (Figures 2 to 4). The Abou has been noted by Thomson *et al.* (1986) as having the highest organic content within the formation. The sections and sampling scheme were arranged so that as much of the Abou section as possible could be sampled. In addition, rocks of the Wolf Den, and Quock members were sampled. The Joan and Melisson members were not developed within the transect areas. Samples were taken roughly every 25 metres with a total of 50 samples analyzed. Structural sections were drawn across the sampling lines and together with geological control from field observations and unit distributions, the samples were placed in an approximate stratigraphic position.

Rock Eval data results shown in Table 1 suggests that little if any hydrogen (HI) remains in the samples due to either oxidation and/or high thermal maturities. Considering these samples were collected from outcrop, oxidation is a likely possibility. Thermal maturation levels are high in this region, with $R_o$ values in nearby Bowser Lake sediments (within 10 km) range between 1.86 and 2.67 (Evenchick *et al.*, 2005) suggesting that these samples are in the upper end of the gas window. Due to the lack of an $S_2$ peak (HI) very little can be inferred about the original type of organic material, although, considering the marine nature of these sediments, it was probably Type I or II. Notwithstanding this, the current levels of total organic carbon (TOC) seen in some sections, particularly across the Abou Member, indicates that it was once a very rich source bed. If one assumes that most of the organic material was expelled during oil and gas generation, then original levels of TOC may have originally ranged between approximately 1 and 20 % assuming only a quarter of the original organic matter remains. The Abou Member currently has TOC values between 3.65 and 4.92 % suggesting original levels of approximately 15 to 20 %. Considering this unit appears to be upwards of 100 metres thick in this area, and 30 metres on average, it had the potential to generate considerable amounts of hydrocarbons. Current TOC levels in the Joan Lake Member are 0.24 to 2.42 % and 1.74 to 3.45 % for the Quock Member, indicating that these too were respectable source beds as well.

ICP-MS analytical results are shown in Table 2. Concentrations of various elements, (*e.g.* Zn, Cu, Ni, Mo) increase within the Abou Member probably reflecting the more anoxic water conditions which facilitated metal precipitation. One sample from this horizon has elevated Ba levels (approximately 1400 ppm or 0.14 %). The Abou Member is time equivalent to the horizon hosting the Eskay Creek mine, a syngenetic silver-rich massive sulphide deposit.

### TABLE 2. MULTI-ELEMENT ICP-MS DATA FOR SPATSIZI FORMATION SAMPLES FROM THE JOAN LAKE AREA. THESE WERE ANALYZED UTILIZING AN AQUA REGIA DIGESTION. UTM COORDINATES IN NAD 27 DATUM.

| | Sample | EPF04-191A | EPF04-191B | EPF04-191C | EPF04-192A | EPF04-192B | EPF04-192C | EPF04-192D | EPF04-193A | EPF04-193B | EPF04-194A | EPF04-194B | EPF04-195A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | easting | 499192 | 499192 | 499192 | 499147 | 499147 | 499147 | 499147 | 499122 | 499122 | 499107 | 499107 | 499100 |
| | northing | 6373564 | 6373564 | 6373564 | 6373447 | 6373447 | 6373447 | 6373447 | 6373305 | 6373305 | 6373190 | 6373190 | 6373077 |
| Mo | ppm | 0.5 | 0.4 | 0.6 | 0.4 | 0.5 | 0.3 | 0.5 | 0.4 | 0.7 | 0.5 | 0.5 | 0.7 |
| Cu | ppm | 29.6 | 36.8 | 32.1 | 28.7 | 36.5 | 25.4 | 35.3 | 35.5 | 38.2 | 26.8 | 27.4 | 33.5 |
| Pb | ppm | 9.3 | 7.7 | 7.9 | 10.5 | 8.5 | 9.4 | 11.2 | 9 | 8.6 | 11.3 | 13.6 | 10.4 |
| Zn | ppm | 120 | 98 | 96 | 83 | 102 | 107 | 107 | 103 | 110 | 77 | 92 | 98 |
| Ag | ppm | 0.1 | 0.1 | <.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Ni | ppm | 21.1 | 21.6 | 18.2 | 14.9 | 19.3 | 21.3 | 21.6 | 18.6 | 22.3 | 17.7 | 24.4 | 18.5 |
| Co | ppm | 9.6 | 8.4 | 6.5 | 5.7 | 8 | 9.8 | 9.1 | 8.5 | 7.5 | 7 | 12.9 | 8 |
| Mn | ppm | 351 | 325 | 196 | 240 | 266 | 352 | 325 | 414 | 243 | 664 | 496 | 451 |
| Fe | % | 4.86 | 4.07 | 4.55 | 4.38 | 4.51 | 4.47 | 5.22 | 4.02 | 4.45 | 3.13 | 4.1 | 3.81 |
| As | ppm | 7.6 | 6.6 | 5.4 | 13.7 | 10.1 | 7.9 | 10.1 | 5.6 | 4.9 | 6.6 | 7 | 4.6 |
| U | ppm | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Au | ppb | <.5 | <.5 | 0.7 | <.5 | <.5 | <.5 | 0.7 | <.5 | <.5 | <.5 | <.5 | <.5 |
| Th | ppm | 1.4 | 1.4 | 1.6 | 1.6 | 1.6 | 2.1 | 1.8 | 1.7 | 1.8 | 1.5 | 1.7 | 1.8 |
| Sr | ppm | 65 | 40 | 17 | 32 | 33 | 81 | 43 | 61 | 25 | 206 | 180 | 141 |
| Cd | ppm | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | <.1 | 0.1 | <.1 | 0.2 | 0.1 | 0.1 |
| Sb | ppm | 0.4 | 0.8 | 0.5 | 2.5 | 1.9 | 0.9 | 1 | 0.5 | 0.6 | 0.4 | 0.5 | 0.4 |
| Bi | ppm | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| V | ppm | 49 | 43 | 44 | 41 | 47 | 36 | 44 | 40 | 48 | 25 | 30 | 35 |
| Ca | % | 1.82 | 1.66 | 0.23 | 0.78 | 0.81 | 2.1 | 1.19 | 1.95 | 0.52 | 5.87 | 4.39 | 3.39 |
| P | % | 0.078 | 0.105 | 0.084 | 0.082 | 0.088 | 0.091 | 0.092 | 0.08 | 0.106 | 0.062 | 0.096 | 0.081 |
| La | ppm | 6 | 9 | 9 | 7 | 8 | 8 | 8 | 8 | 9 | 8 | 8 | 7 |
| Cr | ppm | 61.9 | 40.5 | 49.4 | 38.3 | 45.3 | 33.4 | 35.7 | 39.1 | 42.7 | 27.9 | 32.8 | 36.3 |
| Mg | % | 1.3 | 1.1 | 1.18 | 1.07 | 1.11 | 1.06 | 1.39 | 0.96 | 1.05 | 0.82 | 0.97 | 0.97 |
| Ba | ppm | 131 | 110 | 115 | 130 | 132 | 141 | 146 | 183 | 154 | 150 | 119 | 144 |
| Ti | % | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| B | ppm | 7 | 6 | 8 | 7 | 6 | 7 | 5 | 7 | 5 | 7 | 6 | 7 |
| Al | % | 2.76 | 2.33 | 2.39 | 2.32 | 2.43 | 2.27 | 2.9 | 2.22 | 2.35 | 1.79 | 1.99 | 2.08 |
| Na | % | 0.024 | 0.015 | 0.02 | 0.018 | 0.019 | 0.017 | 0.015 | 0.018 | 0.014 | 0.013 | 0.013 | 0.014 |
| K | % | 0.25 | 0.17 | 0.2 | 0.21 | 0.2 | 0.2 | 0.18 | 0.23 | 0.2 | 0.19 | 0.18 | 0.22 |
| W | ppm | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 |
| Hg | ppm | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 | 0.05 | 0.04 | 0.05 | 0.03 | 0.04 | 0.03 |
| Sc | ppm | 7.8 | 7.4 | 7.3 | 7.2 | 7.1 | 6.2 | 7.2 | 7.1 | 7.2 | 7.5 | 7.2 | 7.2 |
| Tl | ppm | 0.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 |
| S | % | 0.68 | 0.17 | 0.06 | 0.39 | 0.34 | 0.67 | 0.43 | 0.23 | 0.14 | 0.29 | 0.39 | 0.22 |
| Ga | ppm | 6 | 5 | 6 | 5 | 5 | 5 | 6 | 5 | 5 | 4 | 5 | 5 |
| Se | ppm | 0.8 | 1.1 | 0.7 | 0.9 | 0.9 | 0.7 | 0.7 | 0.7 | 1.5 | 0.6 | 0.7 | 0.8 |

## TABLE 2, CONTINUED

| | Sample | EPF04-195B | EPF04-195C | EPF04-195D | EPF04-196A | EPF04-196B | EPF04-197A | EPF04-197B | EPF04-197C | EPF04-198A | EPF04-198B | EPF04-198C | EPF04-198D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | easting | 499100 | 499100 | 499100 | 499110 | 499110 | 499137 | 499137 | 499137 | 499130 | 499130 | 499130 | 499130 |
| | northing | 6373077 | 6373077 | 6373077 | 6372927 | 6372927 | 6372870 | 6372870 | 6372870 | 6372737 | 6372737 | 6372737 | 6372737 |
| Mo | ppm | 0.7 | 0.4 | 0.3 | 1.1 | 0.3 | 0.3 | 0.1 | 0.6 | 1.5 | 1.4 | 12.5 | 28.8 |
| Cu | ppm | 29.8 | 24.9 | 23.9 | 31.5 | 27.6 | 34.2 | 23.7 | 25.8 | 27.6 | 19.9 | 15.6 | 67.7 |
| Pb | ppm | 3.5 | 9.4 | 7.5 | 6.9 | 5.8 | 6.5 | 5.3 | 7.9 | 8.1 | 5 | 6 | 3.5 |
| Zn | ppm | 97 | 90 | 93 | 99 | 91 | 108 | 100 | 76 | 99 | 45 | 100 | 270 |
| Ag | ppm | <.1 | 0.1 | <.1 | <.1 | <.1 | <.1 | <.1 | 0.1 | 0.1 | 0.1 | 0.4 | 0.2 |
| Ni | ppm | 18.7 | 16.2 | 13.5 | 13.9 | 12.9 | 16.1 | 11.7 | 17.1 | 17.9 | 9.8 | 11.7 | 46.5 |
| Co | ppm | 10 | 12 | 8.3 | 8.4 | 7.5 | 10.4 | 8.1 | 9.6 | 6.4 | 1.5 | 0.9 | 2.5 |
| Mn | ppm | 426 | 498 | 602 | 415 | 389 | 440 | 366 | 643 | 282 | 113 | 38 | 339 |
| Fe | % | 4.47 | 3.99 | 4 | 3.56 | 4.49 | 4.84 | 3.58 | 3.15 | 2.93 | 1.74 | 0.92 | 1.42 |
| As | ppm | 4.6 | 4.8 | 3.5 | 2.5 | 3.5 | 3.6 | 2.2 | 6.8 | 5.4 | 3.9 | 7.7 | 8.5 |
| U | ppm | 0.2 | 0.2 | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 | 0.2 | 0.3 | 0.2 | 0.6 | 1.4 |
| Au | ppb | <.5 | <.5 | <.5 | <.5 | <.5 | <.5 | <.5 | <.5 | <.5 | <.5 | <.5 | <.5 |
| Th | ppm | 1.8 | 1.8 | 1.1 | 1 | 1.5 | 1.5 | 1.1 | 1.2 | 1.1 | 0.8 | 0.5 | 1.2 |
| Sr | ppm | 103 | 124 | 218 | 129 | 88 | 89 | 114 | 220 | 41 | 14 | 19 | 131 |
| Cd | ppm | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.7 | 3.5 |
| Sb | ppm | 0.1 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.4 | 0.5 | 0.9 | 1.6 | 1.7 |
| Bi | ppm | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| V | ppm | 42 | 31 | 27 | 27 | 37 | 40 | 32 | 27 | 32 | 27 | 33 | 79 |
| Ca | % | 2.76 | 3.6 | 4.62 | 2.62 | 2.15 | 1.83 | 2.17 | 5.5 | 0.97 | 0.2 | 0.21 | 5.05 |
| P | % | 0.1 | 0.089 | 0.053 | 0.06 | 0.073 | 0.084 | 0.075 | 0.101 | 0.121 | 0.077 | 0.044 | 0.072 |
| La | ppm | 8 | 8 | 5 | 5 | 6 | 7 | 5 | 8 | 9 | 6 | 5 | 7 |
| Cr | ppm | 38.3 | 37.1 | 27.3 | 28.6 | 33.7 | 39.5 | 34.4 | 35.3 | 31.7 | 53.4 | 59.5 | 36.3 |
| Mg | % | 1.12 | 0.95 | 0.96 | 0.82 | 1.08 | 1.13 | 0.86 | 0.63 | 0.5 | 0.26 | 0.1 | 0.22 |
| Ba | ppm | 152 | 124 | 110 | 138 | 121 | 191 | 163 | 167 | 202 | 204 | 144 | 1434 |
| Ti | % | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.047 |
| B | ppm | 6 | 7 | 4 | 4 | 5 | 7 | 7 | 6 | 6 | 5 | 6 | 6 |
| Al | % | 2.4 | 2.08 | 1.96 | 1.78 | 2.17 | 2.4 | 1.98 | 1.44 | 1.37 | 1.02 | 0.49 | 0.68 |
| Na | % | 0.014 | 0.015 | 0.013 | 0.012 | 0.015 | 0.019 | 0.018 | 0.014 | 0.018 | 0.022 | 0.034 | 0.013 |
| K | % | 0.19 | 0.19 | 0.15 | 0.19 | 0.16 | 0.24 | 0.22 | 0.16 | 0.19 | 0.18 | 0.13 | 0.16 |
| W | ppm | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | 0.2 |
| Hg | ppm | 0.02 | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.02 | 0.04 | 0.05 | 0.03 | 0.04 | 0.03 |
| Sc | ppm | 6.7 | 6.8 | 6.7 | 6.3 | 6.6 | 7.3 | 5.4 | 6.6 | 7.2 | 4.2 | 2.2 | 5.1 |
| Tl | ppm | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | 0.1 | 0.1 | 0.5 | 0.5 |
| S | % | <.05 | 0.23 | 0.43 | 0.33 | 0.24 | 0.14 | 0.4 | 0.29 | 0.31 | 0.12 | 0.11 | 0.14 |
| Ga | ppm | 6 | 5 | 5 | 4 | 6 | 6 | 5 | 4 | 3 | 3 | 1 | 2 |
| Se | ppm | <.5 | <.5 | <.5 | <.5 | <.5 | <.5 | <.5 | 0.7 | 1.5 | 2.6 | 4.5 | 4.5 |

## TABLE 2, CONTINUED

|  | Sample | EPF04-199A | EPF04-200A | EPF04-200B | EPF04-201B | EPF04-201C | EPF04-201D | EPF04-202A | EPF04-202B | EPF04-202C | EPF04-202D | EPF04-203A | EPF04-203B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | easting | 499472 | 500666 | 500666 | 500625 | 500625 | 500625 | 500586 | 500586 | 500586 | 500586 | 500527 | 500527 |
|  | northing | 6372793 | 6373358 | 6373358 | 6373340 | 6373340 | 6373340 | 6373235 | 6373235 | 6373235 | 6373235 | 6373166 | 6373166 |
| Mo | ppm | 0.7 | 0.8 | 1.6 | 0.4 | 0.4 | 0.5 | 0.4 | 0.3 | 0.5 | 0.5 | 0.6 | 0.6 |
| Cu | ppm | 24.7 | 11.7 | 12.4 | 29.6 | 29.3 | 38.3 | 31.2 | 34 | 19.8 | 32.8 | 27.3 | 27.5 |
| Pb | ppm | 6.6 | 4.3 | 1.8 | 3.2 | 4 | 7.5 | 8.5 | 9.4 | 12.4 | 10.6 | 10.6 | 10.1 |
| Zn | ppm | 85 | 25 | 30 | 100 | 135 | 105 | 95 | 102 | 56 | 90 | 88 | 82 |
| Ag | ppm | 0.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Ni | ppm | 12.4 | 3.6 | 2.7 | 13.8 | 11.2 | 15.2 | 16.6 | 18.4 | 5.9 | 19.9 | 16.9 | 16.3 |
| Co | ppm | 5.8 | 0.8 | 4.5 | 5.3 | 5.2 | 9.1 | 9.1 | 15.1 | 3.2 | 10.2 | 10.7 | 10.1 |
| Mn | ppm | 315 | 108 | 6358 | 365 | 349 | 135 | 584 | 415 | 55 | 258 | 413 | 362 |
| Fe | % | 3.17 | 2.27 | 2.29 | 4.86 | 4.76 | 3.83 | 4.32 | 5.31 | 2.87 | 4.24 | 4.35 | 4.13 |
| As | ppm | 5.7 | 4.9 | 2.6 | 4 | 2.6 | 3.7 | 4.2 | 5 | 5.8 | 4.8 | 6 | 5.8 |
| U | ppm | 0.2 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 |
| Au | ppb | <.5 | <.5 | <.5 | 0.8 | <.5 | <.5 | 0.5 | <.5 | <.5 | 0.8 | <.5 | <.5 |
| Th | ppm | 1.5 | 0.7 | 0.5 | 1.6 | 1.4 | 1.7 | 1.4 | 1.2 | 1.4 | 1.6 | 1.8 | 1.8 |
| Sr | ppm | 88 | 10 | 317 | 63 | 86 | 27 | 140 | 84 | 10 | 78 | 170 | 126 |
| Cd | ppm | 0.1 | <.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | <.1 | <.1 | 0.1 | 0.1 |
| Sb | ppm | 0.3 | 0.3 | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 0.3 | 0.5 | 0.3 | 0.4 | 0.3 |
| Bi | ppm | 0.1 | 0.1 | <.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| V | ppm | 25 | 17 | 39 | 44 | 35 | 35 | 38 | 57 | 31 | 37 | 32 | 30 |
| Ca | % | 2.32 | 0.08 | 25.16 | 1.8 | 1.98 | 0.73 | 2.98 | 1.81 | 0.09 | 2.04 | 3.96 | 3.13 |
| P | % | 0.069 | 0.029 | 0.04 | 0.085 | 0.07 | 0.066 | 0.088 | 0.084 | 0.077 | 0.088 | 0.108 | 0.089 |
| La | ppm | 8 | 3 | 7 | 4 | 3 | 2 | 3 | 4 | 2 | 3 | 4 | 3 |
| Cr | ppm | 31.8 | 38.9 | 13.5 | 38.7 | 28.8 | 26.2 | 39.7 | 32.5 | 32.4 | 29.9 | 29.4 | 28.6 |
| Mg | % | 0.59 | 0.39 | 0.36 | 1.22 | 1.21 | 0.85 | 0.9 | 1.05 | 0.53 | 0.92 | 0.89 | 0.85 |
| Ba | ppm | 175 | 73 | 42 | 98 | 130 | 152 | 354 | 99 | 142 | 145 | 111 | 101 |
| Ti | % | 0.001 | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| B | ppm | 6 | 3 | 1 | 7 | 6 | 5 | 7 | 6 | 8 | 6 | 6 | 8 |
| Al | % | 1.48 | 1.11 | 0.53 | 2.57 | 2.54 | 2.07 | 2.33 | 2.43 | 1.93 | 2.07 | 2.12 | 1.88 |
| Na | % | 0.016 | 0.024 | 0.012 | 0.018 | 0.013 | 0.014 | 0.021 | 0.019 | 0.017 | 0.017 | 0.015 | 0.015 |
| K | % | 0.2 | 0.1 | 0.01 | 0.2 | 0.21 | 0.19 | 0.31 | 0.15 | 0.27 | 0.21 | 0.23 | 0.2 |
| W | ppm | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 |
| Hg | ppm | 0.03 | 0.04 | 0.01 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.04 |
| Sc | ppm | 7.3 | 3.5 | 6.4 | 7.5 | 7.3 | 8.4 | 10.7 | 10.3 | 9.6 | 10 | 9.7 | 9 |
| Tl | ppm | 0.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 |
| S | % | 0.18 | <.05 | 0.36 | 0.17 | 0.28 | 0.15 | 0.21 | 0.54 | <.05 | 0.19 | 0.65 | 0.39 |
| Ga | ppm | 4 | 5 | 2 | 6 | 6 | 5 | 6 | 6 | 5 | 5 | 5 | 5 |
| Se | ppm | 0.9 | <.5 | 0.8 | 0.6 | <.5 | 0.5 | 0.5 | <.5 | 0.6 | 0.8 | 0.5 | 0.5 |

## TABLE 2, CONTINUED

| | Sample | EPF04-203C | EPF04-203D | EPF04-204A | EPF04-205A | EPF04-205C | EPF04-205D | EPF04-205E | EPF04-206A | EPF04-207A | EPF04-207C | EPF04-207E | EPF04-208A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | easting | 500527 | 500527 | 500472 | 500364 | 500364 | 500364 | 500364 | 500291 | 500253 | 500253 | 500253 | 500189 |
| | northing | 6373166 | 6373166 | 6373038 | 6372621 | 6372621 | 6372621 | 6372621 | 6372595 | 6372571 | 6372571 | 6372571 | 6372496 |
| Mo | ppm | 0.7 | 0.7 | 0.5 | 18.7 | 39.6 | 21.5 | 27.4 | 26.1 | 34.9 | 6.1 | 30.9 | 15.3 |
| Cu | ppm | 29.6 | 30.6 | 22.4 | 46.9 | 6.4 | 57.2 | 42.1 | 50.9 | 21.1 | 6.4 | 33.3 | 28.7 |
| Pb | ppm | 10.3 | 11.1 | 10.6 | 5.5 | 9.2 | 6.2 | 5.7 | 8.9 | 6.6 | 5.3 | 7.7 | 4.5 |
| Zn | ppm | 114 | 98 | 60 | 439 | 58 | 407 | 288 | 358 | 69 | 25 | 144 | 173 |
| Ag | ppm | 0.1 | 0.1 | 0.1 | 0.4 | 0.5 | 0.3 | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 |
| Ni | ppm | 18.3 | 21.6 | 7.6 | 49.3 | 8.4 | 52.9 | 44.7 | 54.3 | 12.3 | 3.6 | 18 | 23.2 |
| Co | ppm | 10.3 | 10.2 | 3.2 | 3.5 | 0.8 | 5 | 3.4 | 4 | 1.4 | 0.4 | 1.8 | 1.3 |
| Mn | ppm | 204 | 380 | 100 | 373 | 6 | 537 | 250 | 210 | 35 | 15 | 46 | 168 |
| Fe | % | 4.87 | 4.25 | 3.64 | 1.55 | 0.44 | 1.89 | 2.12 | 1.97 | 1.05 | 0.52 | 1.73 | 1.6 |
| As | ppm | 5.3 | 4.2 | 4.3 | 10.6 | 16.5 | 15.3 | 12.1 | 17.4 | 14.6 | 7.9 | 17.3 | 9.1 |
| U | ppm | 0.2 | 0.1 | 0.1 | 1 | 0.3 | 1.3 | 1.1 | 0.9 | 1.3 | 0.3 | 0.7 | 1.1 |
| Au | ppb | <.5 | <.5 | 0.5 | 0.8 | 0.8 | <.5 | <.5 | 0.7 | 0.7 | <.5 | 1.3 | <.5 |
| Th | ppm | 1.8 | 1.7 | 1.6 | 0.9 | 0.3 | 0.8 | 1 | 1.7 | 0.8 | 0.5 | 0.8 | 1 |
| Sr | ppm | 29 | 69 | 23 | 93 | 8 | 278 | 41 | 39 | 16 | 7 | 10 | 30 |
| Cd | ppm | 0.1 | 0.2 | <.1 | 9.1 | <.1 | 7.6 | 3.5 | 4.6 | 0.3 | <.1 | 0.3 | 2.1 |
| Sb | ppm | 0.4 | 0.4 | 0.5 | 1.6 | 2.1 | 1.5 | 1.9 | 1.7 | 2.2 | 1.3 | 2.2 | 1.6 |
| Bi | ppm | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| V | ppm | 37 | 36 | 33 | 83 | 52 | 56 | 59 | 63 | 66 | 21 | 36 | 75 |
| Ca | % | 0.4 | 2.17 | 0.22 | 3.77 | 0.05 | 6.88 | 1.77 | 1.53 | 0.22 | 0.05 | 0.1 | 0.59 |
| P | % | 0.103 | 0.085 | 0.081 | 0.064 | 0.009 | 0.072 | 0.075 | 0.044 | 0.089 | 0.044 | 0.059 | 0.071 |
| La | ppm | 4 | 3 | 3 | 9 | 2 | 10 | 7 | 8 | 6 | 6 | 6 | 8 |
| Cr | ppm | 34.5 | 35.5 | 39.2 | 35.3 | 37.9 | 38.4 | 28.8 | 32.4 | 34.9 | 44.9 | 23 | 39.2 |
| Mg | % | 0.89 | 0.87 | 0.72 | 0.26 | 0.03 | 0.16 | 0.32 | 0.3 | 0.18 | 0.06 | 0.25 | 0.28 |
| Ba | ppm | 144 | 137 | 174 | 184 | 155 | 153 | 148 | 169 | 161 | 152 | 187 | 250 |
| Ti | % | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | <.001 | 0.001 | 0.001 | <.001 | 0.001 |
| B | ppm | 5 | 7 | 5 | 5 | 3 | 4 | 4 | 6 | 4 | 3 | 4 | 5 |
| Al | % | 2.2 | 2.16 | 1.92 | 0.74 | 0.38 | 0.5 | 0.88 | 0.85 | 0.62 | 0.37 | 0.69 | 0.94 |
| Na | % | 0.015 | 0.013 | 0.014 | 0.013 | 0.025 | 0.016 | 0.014 | 0.014 | 0.015 | 0.019 | 0.015 | 0.013 |
| K | % | 0.22 | 0.24 | 0.25 | 0.16 | 0.15 | 0.13 | 0.13 | 0.19 | 0.14 | 0.13 | 0.17 | 0.18 |
| W | ppm | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 |
| Hg | ppm | 0.04 | 0.04 | 0.03 | 0.06 | 0.09 | 0.07 | 0.06 | 0.07 | 0.08 | 0.07 | 0.07 | 0.05 |
| Sc | ppm | 10.5 | 8.7 | 6.9 | 6.8 | 3.1 | 8.7 | 6.1 | 5.8 | 4.4 | 2 | 4.6 | 5.5 |
| Tl | ppm | <.1 | <.1 | <.1 | 0.6 | 1.1 | 0.5 | 0.7 | 0.7 | 0.5 | 0.3 | 0.6 | 0.5 |
| S | % | 0.14 | 0.23 | <.05 | <.05 | 0.09 | 0.78 | 0.07 | 0.13 | <.05 | 0.06 | <.05 | <.05 |
| Ga | ppm | 5 | 5 | 5 | 2 | 1 | 2 | 2 | 2 | 2 | 1 | 3 | 2 |
| Se | ppm | 0.6 | 0.6 | 0.7 | 8.4 | 8.7 | 5.2 | 5.9 | 7.1 | 3.4 | 3.8 | 5.1 | 3.8 |

## TABLE 2, CONTINUED

| | Sample | EPF04-209A | EPF04-210A | FF04-1A | FF04-1B | FF04-1E | FF03-1A | FF03-13A | FF03-13B | FF03-15A | FF03-15B | FF03-15C | FF03-2A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | easting | 500068 | 499972 | 619543 | 619543 | 619543 | 621033 | 589945 | 589945 | 600523 | 600523 | 600523 | 621066 |
| | northing | 6372471 | 6372463 | 5613654 | 5613654 | 5613654 | 5620414 | 5833905 | 5833905 | 5566989 | 5566989 | 5566989 | 5620479 |
| Mo | ppm | 6.1 | 13.7 | 4.2 | 0.6 | 0.3 | 7.9 | 43.5 | 17.8 | 1 | 1.3 | 0.2 | 11 |
| Cu | ppm | 18.4 | 23.2 | 86.6 | 72.1 | 1.3 | 14.7 | 91 | 86.8 | 46.1 | 24 | 58.4 | 44.9 |
| Pb | ppm | 3.6 | 8.9 | 13.7 | 4.9 | <.1 | 12.2 | 7.4 | 6.1 | 5 | 5.2 | 6.8 | 10.6 |
| Zn | ppm | 122 | 118 | 173 | 135 | 2 | 25 | 441 | 354 | 59 | 60 | 83 | 154 |
| Ag | ppm | 0.1 | 0.2 | 0.2 | 0.1 | <.1 | 0.1 | 0.5 | 0.5 | <.1 | <.1 | 0.1 | 0.1 |
| Ni | ppm | 23.9 | 16.3 | 44.8 | 34.7 | 0.8 | 4.3 | 175.4 | 75.9 | 15.4 | 21.5 | 30.8 | 28.8 |
| Co | ppm | 1.1 | 1.3 | 12.9 | 8.2 | 0.1 | 1.4 | 7.2 | 5.1 | 9.1 | 10.1 | 13.2 | 10.4 |
| Mn | ppm | 1092 | 88 | 548 | 504 | 2854 | 20 | 347 | 570 | 841 | 914 | 374 | 421 |
| Fe | % | 1.31 | 1.8 | 3.62 | 3.25 | 0.48 | 0.74 | 2.08 | 2.03 | 3.9 | 3.19 | 2.81 | 1.81 |
| As | ppm | 5.3 | 12 | 18.5 | 5 | 0.8 | 16.8 | 27.5 | 21.2 | 10.3 | 10.3 | 1.3 | 11.7 |
| U | ppm | 0.6 | 0.5 | 0.5 | 0.4 | 0.1 | 0.7 | 3.7 | 1.4 | 1.2 | 0.3 | 0.2 | 0.9 |
| Au | ppb | 1.1 | 1 | 1.4 | 0.5 | 1.3 | 1.4 | 1 | 0.8 | 0.8 | 1.6 | 0.8 | <.5 |
| Th | ppm | 0.8 | 0.8 | 2.6 | 2.7 | <.1 | 4.6 | 1.1 | 0.9 | 1.1 | 1.3 | 0.8 | 2.8 |
| Sr | ppm | 354 | 10 | 207 | 167 | 3138 | 37 | 743 | 753 | 366 | 262 | 91 | 205 |
| Cd | ppm | 2 | 0.4 | 1.4 | 1 | 0.1 | 0.1 | 4.9 | 4 | 0.3 | 0.2 | 0.2 | 1.6 |
| Sb | ppm | 0.8 | 1.3 | 2 | 0.4 | 0.1 | 1 | 2.9 | 3.3 | 0.6 | 0.8 | 0.1 | 1.5 |
| Bi | ppm | 0.1 | 0.1 | 0.1 | 0.2 | <.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 |
| V | ppm | 70 | 60 | 78 | 71 | 4 | 10 | 195 | 180 | 67 | 41 | 47 | 17 |
| Ca | % | 8.03 | 0.15 | 3.35 | 2.99 | 31.82 | 0.33 | 9.84 | 14.66 | 11.11 | 10.24 | 1.6 | 4.13 |
| P | % | 0.038 | 0.037 | 0.118 | 0.118 | 0.022 | 0.036 | 0.156 | 0.091 | 0.436 | 0.109 | 0.06 | 0.056 |
| La | ppm | 7 | 4 | 9 | 10 | <1 | 20 | 6 | 5 | 28 | 13 | 9 | 7 |
| Cr | ppm | 63.3 | 60.5 | 50.2 | 51.5 | 11.5 | 53.3 | 40.6 | 42.9 | 25.7 | 31.9 | 30.3 | 15.5 |
| Mg | % | 0.5 | 0.6 | 1.31 | 1.43 | 0.48 | 0.05 | 0.31 | 0.36 | 1.07 | 0.81 | 0.88 | 0.1 |
| Ba | ppm | 140 | 117 | 148 | 123 | 225 | 238 | 75 | 95 | 389 | 195 | 132 | 54 |
| Ti | % | 0.001 | 0.001 | 0.003 | 0.003 | <.001 | 0.002 | 0.001 | 0.001 | 0.056 | 0.067 | 0.092 | 0.002 |
| B | ppm | 2 | 2 | 17 | 19 | 1 | 11 | 16 | 9 | 5 | 6 | 6 | 11 |
| Al | % | 0.75 | 0.95 | 2.17 | 2.12 | 0.03 | 0.51 | 0.59 | 0.43 | 2.36 | 1.89 | 2.37 | 0.39 |
| Na | % | 0.021 | 0.03 | 0.016 | 0.038 | 0.009 | 0.059 | 0.027 | 0.018 | 0.015 | 0.015 | 0.014 | 0.038 |
| K | % | 0.09 | 0.13 | 0.5 | 0.49 | 0.01 | 0.43 | 0.23 | 0.16 | 0.18 | 0.24 | 0.29 | 0.36 |
| W | ppm | <.1 | <.1 | <.1 | <.1 | 0.1 | <.1 | <.1 | <.1 | 0.7 | 0.2 | 0.1 | <.1 |
| Hg | ppm | 0.02 | 0.06 | 0.13 | 0.03 | 0.01 | 0.03 | 0.15 | 0.15 | 0.11 | 0.06 | 0.02 | 0.08 |
| Sc | ppm | 4.1 | 4.1 | 7.9 | 6.5 | 0.3 | 1.5 | 8.3 | 6.2 | 4.8 | 5.4 | 7.1 | 4.3 |
| Tl | ppm | 0.4 | 0.3 | 0.2 | 0.1 | <.1 | 0.1 | 0.5 | 0.2 | <.1 | <.1 | 0.1 | 0.3 |
| S | % | <.05 | <.05 | 0.28 | 0.09 | 0.14 | 0.26 | 1.93 | 1.8 | 0.06 | 0.51 | <.05 | 1.72 |
| Ga | ppm | 2 | 3 | 7 | 7 | <1 | 2 | 2 | 2 | 5 | 4 | 6 | 1 |
| Se | ppm | 1.4 | 3.1 | 2.2 | 1.1 | 0.6 | 1.3 | 14.2 | 11.7 | 1.1 | 0.8 | <.5 | 2.3 |

**TABLE 2, CONTINUED**

| | Sample | FF03-2B | FF03-3A | FF03-4A | FF03-4B | FF03-5A | FF03-6A | FF03-8A |
|---|---|---|---|---|---|---|---|---|
| | easting | 621066 | 621073 | 621106 | 621106 | 621140 | 621147 | 621046 |
| | northing | 5620479 | 5620505 | 5620590 | 5620590 | 5620636 | 5620691 | 5620363 |
| Mo | ppm | 8.7 | 10.4 | 12.7 | 11.8 | 24.7 | 36.9 | 10.1 |
| Cu | ppm | 30.6 | 43.1 | 41.9 | 41.8 | 49.2 | 64.5 | 40 |
| Pb | ppm | 9.7 | 10.1 | 9.4 | 9.1 | 7.5 | 8.6 | 10.5 |
| Zn | ppm | 111 | 128 | 141 | 132 | 304 | 437 | 129 |
| Ag | ppm | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 |
| Ni | ppm | 18.7 | 26.8 | 26.2 | 23.1 | 55.9 | 78.9 | 23.7 |
| Co | ppm | 8 | 9.1 | 9.6 | 8.6 | 9.6 | 12.6 | 9.1 |
| Mn | ppm | 914 | 379 | 670 | 674 | 460 | 409 | 592 |
| Fe | % | 1.42 | 1.61 | 2.43 | 3.4 | 1.99 | 2.56 | 2.28 |
| As | ppm | 10.1 | 10.1 | 11.7 | 11.8 | 14.7 | 19.5 | 12.1 |
| U | ppm | 0.9 | 0.7 | 0.9 | 0.9 | 1.1 | 1.4 | 0.8 |
| Au | ppb | <.5 | <.5 | <.5 | 0.7 | 0.6 | <.5 | <.5 |
| Th | ppm | 2.8 | 2.3 | 2.8 | 2.6 | 2.1 | 2 | 2.6 |
| Sr | ppm | 224 | 236 | 265 | 300 | 313 | 311 | 265 |
| Cd | ppm | 1.1 | 1.5 | 1.6 | 1.4 | 3.1 | 4.6 | 1.3 |
| Sb | ppm | 1 | 1.3 | 1.1 | 1.1 | 2.9 | 3.7 | 1.2 |
| Bi | ppm | 0.1 | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 |
| V | ppm | 12 | 14 | 14 | 13 | 36 | 39 | 16 |
| Ca | % | 6 | 4.61 | 7.66 | 7.13 | 8.39 | 7.34 | 5.4 |
| P | % | 0.047 | 0.055 | 0.059 | 0.053 | 0.064 | 0.068 | 0.054 |
| La | ppm | 10 | 5 | 5 | 7 | 3 | 2 | 8 |
| Cr | ppm | 14.9 | 15 | 12.4 | 12.5 | 15.7 | 16.2 | 16.2 |
| Mg | % | 0.12 | 0.18 | 0.22 | 0.2 | 0.58 | 0.33 | 0.1 |
| Ba | ppm | 152 | 83 | 83 | 79 | 101 | 85 | 95 |
| Ti | % | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 |
| B | ppm | 10 | 9 | 10 | 9 | 12 | 7 | 9 |
| Al | % | 0.45 | 0.4 | 0.4 | 0.39 | 0.41 | 0.4 | 0.44 |
| Na | % | 0.033 | 0.703 | 0.776 | 0.268 | 0.44 | 0.071 | 0.023 |
| K | % | 0.43 | 0.35 | 0.29 | 0.38 | 0.26 | 0.21 | 0.4 |
| W | ppm | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 |
| Hg | ppm | 0.05 | 0.08 | 0.08 | 0.08 | 0.09 | 0.14 | 0.06 |
| Sc | ppm | 4 | 3.9 | 4.5 | 4.4 | 5.8 | 6.8 | 4.2 |
| Tl | ppm | 0.2 | 0.5 | 0.3 | 0.3 | 1.5 | 0.7 | 0.3 |
| S | % | 1.31 | 1.77 | 2.28 | 3.62 | 2.85 | 3.07 | 2.18 |
| Ga | ppm | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| Se | ppm | 1.5 | 5.4 | 6 | 6.1 | 5 | 6 | 2.2 |

## TABLE 3. MULTI-ELEMENT ICP-MS DATA FOR SPATSIZI FORMATION SAMPLES FROM THE JOAN LAKE AREA. THESE WERE ANALYZED UTILIZING A TOTAL ACID DIGESTION. UTM COORDINATES IN NAD 27 DATUM.

|  | Sample | EPF04-191A | EPF04-192C | EPF04-194B | EPF04-196A | EPF04-198A | EPF04-200A | EPF04-202A | EPF04-203B | EPF04-205C | EPF04-207C | EPF04-210A | FF04-01B | FF03-001A | FF03-015C | FF03-004B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | easting | 499192 | 499147 | 499107 | 499110 | 499130 | 500666 | 500586 | 500527 | 500364 | 500253 | 499972 | 619543 | 621033 | 600523 | 621106 |
|  | northing | 6373564 | 6373447 | 6373190 | 6372927 | 6372737 | 6373358 | 6373235 | 6373166 | 6372621 | 6372571 | 6372463 | 5613654 | 5620414 | 5566989 | 5620590 |
| Mo | ppm | 1 | 0.7 | 0.7 | 1.3 | 2 | 1 | 0.4 | 0.8 | 43.1 | 6.6 | 14.1 | 0.9 | 9.3 | 0.3 | 13.3 |
| Cu | ppm | 31.7 | 28.4 | 29.5 | 34.5 | 28.1 | 12.4 | 31.9 | 30.3 | 7.1 | 6.4 | 24.9 | 78.1 | 16.5 | 62.6 | 44.6 |
| Pb | ppm | 9.9 | 11.2 | 13.4 | 7.4 | 7.6 | 5.1 | 8.4 | 10.6 | 8.9 | 4.8 | 8.1 | 6.3 | 12.8 | 7.9 | 9.4 |
| Zn | ppm | 133 | 116 | 99 | 114 | 111 | 32 | 107 | 97 | 61 | 28 | 130 | 171 | 35 | 104 | 168 |
| Ag | ppm | <.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | <.1 | 0.1 | 0.8 | 0.4 | 0.3 | 0.1 | 0.1 | 0.1 | 0.2 |
| Ni | ppm | 23 | 22.1 | 28.2 | 15.7 | 19.7 | 5.1 | 15.6 | 18.5 | 13.5 | 6.1 | 16.7 | 42.1 | 6.2 | 38.2 | 25.8 |
| Co | ppm | 9 | 10 | 13 | 8 | 6 | 1 | 8 | 11 | 1 | <1 | 1 | 8 | 1 | 15 | 8 |
| Mn | ppm | 370 | 386 | 528 | 472 | 281 | 131 | 564 | 372 | 11 | 18 | 89 | 588 | 50 | 488 | 747 |
| Fe | % | 5.35 | 5.3 | 4.59 | 4.17 | 3.39 | 2.87 | 4.5 | 4.48 | 0.59 | 0.63 | 1.94 | 4.02 | 1.57 | 3.89 | 4.4 |
| As | ppm | 8 | 10 | 7 | 3 | 5 | 6 | 5 | 6 | 17 | 8 | 12 | 5 | 20 | 3 | 16 |
| U | ppm | 0.9 | 1.5 | 1.1 | 0.9 | 0.9 | 1 | 0.8 | 1 | 4.2 | 2.8 | 2.9 | 2.2 | 5.2 | 0.6 | 3.4 |
| Au | ppm | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 |
| Th | ppm | 3 | 4.5 | 3.2 | 2.6 | 2 | 2 | 2.8 | 3.3 | 1.2 | 1.3 | 1.7 | 5.4 | 9.8 | 2.3 | 5.1 |
| Sr | ppm | 139 | 155 | 244 | 200 | 87 | 127 | 184 | 195 | 48 | 42 | 46 | 214 | 90 | 150 | 332 |
| Cd | ppm | 0.2 | 0.2 | 0.1 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 | 0.3 | 0.7 | 1.3 | 0.3 | 0.3 | 1.5 |
| Sb | ppm | 1 | 1.9 | 0.9 | 0.6 | 1 | 0.8 | 0.7 | 0.8 | 4 | 2.3 | 1.8 | 0.9 | 1.9 | 0.4 | 2 |
| Bi | ppm | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | <.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 |
| V | ppm | 148 | 127 | 118 | 116 | 111 | 46 | 115 | 120 | 383 | 164 | 127 | 196 | 61 | 144 | 126 |
| Ca | % | 2.1 | 2.5 | 4.94 | 3.04 | 1.15 | 0.13 | 3.04 | 3.42 | 0.06 | 0.06 | 0.13 | 3.49 | 0.39 | 2.04 | 8.03 |
| P | % | 0.086 | 0.125 | 0.109 | 0.075 | 0.134 | 0.039 | 0.093 | 0.108 | 0.013 | 0.05 | 0.037 | 0.133 | 0.045 | 0.081 | 0.057 |
| La | ppm | 12.1 | 14 | 15.8 | 15.8 | 17 | 4.1 | 8.1 | 7.5 | 5.6 | 12.2 | 4.2 | 20.5 | 24.8 | 16.9 | 13.2 |
| Cr | ppm | 97.5 | 68.1 | 65.5 | 60.7 | 58.8 | 67.6 | 68.1 | 64 | 66.5 | 77.8 | 84.3 | 113.3 | 92.9 | 66.8 | 37.3 |
| Mg | % | 1.38 | 1.33 | 1.17 | 1.11 | 0.65 | 0.53 | 1.01 | 1.01 | 0.2 | 0.23 | 0.69 | 2.09 | 0.3 | 1.43 | 0.54 |
| Ba | ppm | 910 | 686 | 928 | 1080 | 686 | 401 | 1074 | 823 | 968 | 982 | 498 | 551 | 1019 | 528 | 31 |
| Ti | % | 0.476 | 0.442 | 0.416 | 0.451 | 0.337 | 0.255 | 0.424 | 0.428 | 0.336 | 0.271 | 0.208 | 0.434 | 0.198 | 0.394 | 0.243 |
| Al | % | 8.56 | 8.43 | 7.69 | 7.75 | 6.08 | 4.87 | 7.73 | 7.79 | 5.19 | 4.46 | 3.93 | 7.59 | 7.22 | 7.31 | 5.28 |
| Na | % | 1.239 | 1.315 | 1.276 | 1.275 | 1.401 | 1.501 | 1.151 | 1.431 | 1.964 | 1.388 | 1.457 | 1.428 | 3.599 | 0.404 | 1.569 |
| K | % | 1.91 | 1.84 | 1.73 | 1.82 | 1.3 | 0.75 | 1.85 | 1.85 | 0.97 | 0.94 | 0.61 | 2.42 | 1.87 | 1.48 | 1.91 |
| W | ppm | 0.7 | 0.9 | 0.7 | 0.7 | 0.7 | 0.4 | 0.6 | 0.7 | 0.5 | 0.5 | 0.4 | 1 | 1 | 0.4 | 0.8 |
| Zr | ppm | 34.6 | 46 | 42.4 | 31 | 40.1 | 36.8 | 33.4 | 38.1 | 66.4 | 57.7 | 48.9 | 70.8 | 111 | 59.1 | 75 |
| Ce | ppm | 23 | 25 | 28 | 30 | 27 | 7 | 17 | 16 | 10 | 20 | 8 | 37 | 48 | 35 | 31 |
| Sn | ppm | 1.4 | 1.4 | 0.9 | 1 | 0.9 | 0.8 | 1 | 1.1 | 0.8 | 1 | 0.7 | 1.5 | 1.8 | 0.9 | 1.2 |
| Y | ppm | 18.1 | 19.5 | 19.9 | 17.2 | 23.8 | 8.2 | 16.3 | 16 | 9.6 | 8.9 | 10.3 | 22.1 | 22.8 | 15.6 | 22.3 |
| Nb | ppm | 6.3 | 6 | 5.9 | 5.5 | 3.8 | 2.9 | 5.7 | 6.4 | 2.4 | 2.5 | 2 | 6.7 | 7.1 | 3.2 | 4.5 |
| Ta | ppm | 0.4 | 0.6 | 0.4 | 0.3 | 0.3 | 0.2 | 0.3 | 0.4 | 0.1 | 0.1 | 0.1 | 0.5 | 0.6 | 0.2 | 0.4 |
| Be | ppm | 1 | 1 | 1 | 1 | 1 | <1 | 1 | 1 | 1 | <1 | <1 | 1 | 2 | 1 | 1 |
| Sc | ppm | 21 | 18 | 16 | 19 | 17 | 11 | 18 | 17 | 11 | 10 | 9 | 15 | 7 | 15 | 8 |
| Li | ppm | 48.3 | 50.4 | 36.1 | 32.3 | 20.4 | 22.1 | 30.1 | 32.9 | 1.2 | 1.7 | 6.9 | 58.1 | 4.7 | 35 | 8.6 |
| S | % | 0.7 | 0.9 | 0.5 | 0.4 | 0.4 | 0.1 | 0.2 | 0.5 | 0.2 | 0.1 | <.1 | <.1 | 0.4 | <.1 | 3.7 |
| Rb | ppm | 74.5 | 72.8 | 69.3 | 68.2 | 44.4 | 28.4 | 70.2 | 70.9 | 28.1 | 26.6 | 15.3 | 91.3 | 72.5 | 52 | 64.5 |
| Hf | ppm | 1.4 | 1.8 | 1.4 | 1.2 | 1.2 | 1.5 | 1.1 | 1.5 | 2 | 1.9 | 1.7 | 2.8 | 4.8 | 2 | 3.1 |

### *McConnell Creek and Oweegee Dome Areas*

In western McConnell Creek, rocks of the Spatsizi Formation show similar compositional trends to those in the Joan Lake area suggesting effects from oxidation and thermal maturation (Figure 5; Table 1). Surface thermal maturation levels, based on vitrinite reflectance data, for Spatsizi rocks in McConnell Creek range from 1.6 to greater that 2.4% (V. Stasiuk, personal communication). Current TOC levels are similar to those seen in the Joan Lake area, ranging between 0.27 to 6.01 % (*see* Table 1).

Oweegee Dome (see Figure 1 for approximate location) is believed to represents a structural window exposing Jurassic and older basement to the Bowser Lake Group. The Spatsizi Formation is exposed below Bowser Lake Group sediments around the entire structure and is several hundred metres in thickness. As in the McConnell Creek area, it is not possible to differentiate all the members defined by Thomson *et al.* (1986) in the Joan Lake area. Lithologically, the section appears most similar to the Wolf Den Member. The upper half of the Spatsizi section in the northern Oweegee Dome area does not contain well developed tuffaceous horizons of the Quock Member. Instead, the dark siltstones are punctuated by distinctive brown weathering, feldspathic chert sandstone sheets up to several metres thick which, together with features in thinner beds, suggest deposition as turbidic flows. Intervening siltstone may be siliceous and contain thin tuffaceous horizons. This section passes upwards into crumbly siltstone and grey-brown sandstones typical of the Ritchie-Alger lithofacies assemblage.

Several samples were acquired along the northern part of Oweegee Dome returning TOC levels between 0.23 and 1.69 %. Surface $R_o$ levels for Spatsizi and Bowser rocks in the vicinity of the sample localities are between 1.53 and 5%

### *Un-named Early Middle Jurassic Rocks*

#### *Likely Area*

In the Likely area, Early to Middle Jurassic organic-rich shales and calcareous shales were also sampled for determining organic content (Figure 6; Ferri *et al.*, 2004). TOC values shown in Table 1 are 5.5 and 5.05 %. Thermal maturities at this locality, based on vitrinite reflectance, is in the order of $R_o = 2.11$ (V. Stasiuk, personal communication, 2005), which would explain the low HI levels.

### *Ashcroft Formation*

#### *Ashcroft Area*

Sampling in 2003 took place along Highway 97C which leads into the town of Ashcroft (Figure 7). Possible oil shales described along Minaberriet Creek (Macauley, 1984) were sampled during the summer of 2004. Analyses of these samples are shown in Table 1. Thermal maturation levels, based on vitrinite reflectance data, indicate Ro levels of 1.96 to 2.73% (V. Stasiuk, personal communication, 2005). As in samples from other regions, $S_2$ values are 0 or less than 0.2, although TOC values range from 0.6 to 5.09 %.

## DISCUSSION

The compositional and lithological similarities of Early to Middle Jurassic black clastic sequences observed in Bowser Basin and the southern Intermontane region suggests widespread deposition (Ferri *et al.*, 2004). In addition, Rock Eval data indicates these horizons are rich in organic matter, containing approximately 1 to 6 % TOC. In all areas sampled, thermal maturation levels were high, being at, or exceeding the upper end of the gas window. These high temperatures, together with possible surface oxidation, probably explain the low $S_2$ (HI) levels observed in the analysis.

Assuming that a considerable amount of the organic matter was driven off during thermal maturation, it is conceivable that these rocks originally had a much higher organic content. As surmised earlier, original TOC may have ranged from 1 to 20 % with some zones having contents between 15 and 20 %.

Although all areas examined as part of this study are overmature, it is possible that in other regions equivalent horizons may occur in the proper thermal window and act as effective source beds. These fine clastic sequences are temporally and lithologically equivalent to the Fernie Group of the Western Canada Sedimentary Basin. TOC levels for the Fernie Group, particularly the Nordegg and equivalent members, are similar to original levels postulated for rocks of this study (Riediger, 2002).

## ACKNOWLEDGEMENTS

The authors would like to thank Canadian Helicopters, particularly Darrell Adzich, for timely and safe transportation. We would also like to acknowledge the staff at Bell II for providing excellent base camp accommodation. We appreciate the timely assistance of staff at the Smithers office of the Ministry of Water, Land and Air Protection in providing us with a permit to carry out our research. A special thanks goes to Nicola Focht of The Exploration Place, and Jamel Joseph of the Geological Survey of Canada, for their assistance in the field.

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