

## Source of the Chinkeh oil from Maxhamish field, Liard Basin, northeastern British Columbia

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### Introduction

The Lower Cretaceous Chinkeh Formation of Liard Basin in northeastern British Columbia and southwestern Northwest Territories is an irregular blanket of sandstone of up to 32 meter thick. Located at a depth of ~1600 meters and spanning over 2000 km<sup>2</sup> in the Maxhamish area, the Chinkeh Formation is overlain by 200-250 m of black, silty shale and mudstone of the Cretaceous Garbutt Fm, and unconformably overlies sandstone and shale of the Triassic Toad Formation (Leckie *et al.*, 1991; Leckie and Potocki, 1998; Morrow and Shinduke, 2003). Shale intervals from the lower part of the Garbutt formation were found to be thermally mature and have fair to good source-rock potential (Leckie, *et al.*, 1991). The underlying Triassic Toad Fm was also considered to contain potential source rocks. With 8-15% porosity, potential source rocks nearby and favorable levels of maturation the Chinkeh Fm sandstones were proposed as a frontier-type play in the early 1990's. Exploration in the last two decades has resulted in discovery of 300- 400 Bcf gas in place and 400-500 million barrels of light oil in place in the Chinkeh Fm at Maxhamish. Despite its relatively small reserve, the Chinkeh oil at Maxhamish has attracted industrial interest regarding its main source rock(s) and its relationship to the gas, information that should provide some guidance for future oil and gas exploration in the area. This study presents preliminary geochemical results and interpretations for the Chinkeh oil based on limited samples.

### Method

Light crude oil samples were collected from eight horizontal wells producing from the Chinkeh Fm at Maxhamish field. The oil samples have been subjected to detailed geochemical analysis including (1) whole oil gas-chromatography (GC) analysis for total hydrocarbon fingerprinting; (2) gas chromatography-mass spectrometry (GC-MS) analysis of saturated and aromatic fractions for their biomarker compositions; (3) their contents of organic sulfur, and (4) their bulk carbon isotope compositions. To infer the main source rocks of the Chinkeh oil accumulation, their geochemical signatures are to be compared against those of the crude oils typically sourced from the Devonian, Triassic, Jurassic and Cretaceous shale intervals in WCSB and Mackenzie Corridor basins.

### Results

The Chinkeh oils collected from Maxhamish field have a measured API gravity of 39.2–41.4° and a sulfur content of ~0.08%, common properties of light sweet oil. Figure 1 shows a typical hydrocarbon fingerprint of Chinkeh oil obtained from whole oil GC analysis. Their GC traces are dominated by n-alkanes, cyclic alkanes and acyclic iso-alkanes. Aromatic hydrocarbons are minor components in the Chinkeh oils, with a ratio of benzene to cyclohexane (Ben/CYC6) and toluene to methyl cyclohexane (Tol/MCYC6) in the range of 0.16–0.21 and 0.29–0.39. Depending on the preservation condition of the oil samples prior to lab analysis, the relative amount of C<sub>4</sub>-C<sub>5</sub> alkanes can vary significantly; however, n-alkanes as heavy as

C<sub>30</sub>-C<sub>35</sub> are apparently present in the oils and C<sub>20</sub><sup>+</sup> hydrocarbons can account for as much as 10% of the GC-amenable hydrocarbons. The Chinkeh oils have a pristine over phytane (Pr/Ph) ratio of 1.5–1.8; a pristine over C<sub>17</sub> n-alkane (pr/nC<sub>17</sub>) ratio of 0.59–0.64, and a phytane over C<sub>18</sub> n-alkane (Ph/nC<sub>18</sub>) ratio of 0.44–0.51.

Shown in Figure 2 are the mass chromatograms m/z 217 and 218 showing the distribution of steranes and m/z 191 showing the distribution of tricyclic and pentacyclic terpanes (e.g. hopanes) for a typical Chinkeh oil. Diasteranes (or re-arranged steranes) dominate on the m/z 217 mass chromatogram, and m/z 191 trace is dominated by tricyclic terpanes. While the relative enrichment of these two types of compounds suggests a high level of thermal maturity experienced by the oils or their source rocks as these biomarkers are thermally more stable than regular steranes and pentacyclic terpanes, this also indicates a shaly source rock for the Chinkeh oil accumulation as these compounds are mostly derived from organic matter associated with argillaceous sediments (Peters et al., 2005). This is further supported by their Pr/Ph ratio >1 from whole GC analysis and dibenzothiophene over phenanthrene ratio (DBT/Phen) of 0.19–0.28 from aromatic GC-MS analysis. Hughes et al (1995) reported that crude oils sourced from marine shale have a DBT/Phen ratio <1 and a Pr/Ph ratio >1 and <3. The abundant occurrence of C<sub>30</sub> 4-desmethyl steranes (m/z 217 and 218 in Fig 2) in the Chinkeh oils also indicates a contribution from marine source rocks.

The total hydrocarbon fingerprint of the Chinkeh oils indicates their main source rocks are mature in the oil window. The 20R to 20S isomerization of  $\alpha\alpha\alpha$ C<sub>29</sub> steranes has reached its equilibrium for the Chinkeh oil samples in this study, with a 20S/(20S+20R) ratio being in the range of 0.56–0.64. Maturity parameters based on the thermal isomerization of alkyl naphthalenes and phenanthrenes produce an estimated vitrinite reflectance in the range of 0.81–1.0% Ro. Therefore, the Chinkeh oil accumulation has been likely sourced from a marine shale interval at its late or post-peak oil generation window.

Based on currently available geochemical information, the Devonian shales are not considered to have made any significant contribution to the Chinkeh oil accumulation in Maxhamish field. While recent industrial exploration and academic research have identified the mature to overmature organic-rich Devonian Besa River, Horn River, Muskwa, Evie and/or Exshaw shale intervals as important shale hydrocarbon plays in the Liard basin and the adjacent Horn River basin, its contribution to the Chinkeh oil accumulation is likely minimal based on the biomarker signatures of the Chinkeh liquid. As shown on m/z 218 in Figure 2, the Chinkeh oils have a 34%-33%-33% of C<sub>27</sub>-C<sub>28</sub>-C<sub>29</sub> sterane distribution. This is very different from that of the Devonian sourced oils in the Mackenzie Corridor basins and the WCSB (Fig 3). Crude oils derived from the Devonian Canol shale such as the Norman Wells field in the Mackenzie Corridor have a sterane carbon number pattern of C<sub>29</sub>>C<sub>27</sub>>>C<sub>28</sub> (Snowdon et al. 1978; Fig 3). Similarly, crude oils sourced from the shale intervals of Devonian Duvernay, Exshaw and Bakken formations in WCSB have a sterane distribution pattern of C<sub>29</sub>≈C<sub>27</sub>>>C<sub>28</sub> (Creaney et al., 1991; Fig 3). The sharp difference in the sterane carbon number distributions indicates that the main source rock of the Chinkeh oil have an input of phytoplankton assemblage distinct from the Devonian shales.

Based on their geological setting, organic richness and thermal maturity as well as the presence of pyrobitumen in the Chinkeh sandstones, Leckie *et al* (1991) proposed the Cretaceous Garbutt shale and the underlying Triassic Toad/Grayling shale to be the potential source rocks to the oil accumulations in the Chinkeh Fm. Since no geochemical biomarker data are currently available for Triassic Toad/Grayling shale samples from Liard basin and the adjacent Horn River basin for the purpose of oil-source correlation, Triassic Doig-sourced crude oils from WCSB are used to infer the likely biomarker signature of liquid hydrocarbons generated by Toad/Grayling shales. On the m/z 218 mass chromatograms (Fig 3; and Creaney et al, 1991), both C<sub>27</sub> and C<sub>29</sub> steranes dominate over their C<sub>28</sub> counterparts for the Doig oils in the WCSB. This is in sharp contrast to the near equal percentage of C<sub>27</sub>-C<sub>28</sub>-C<sub>29</sub> sterane

distribution detected in the Chinkeh oils. Therefore the Triassic Toad/Grayling shale does not seem to be the main source contributor either to the oil accumulation in the overlying Chinkeh sandstone reservoir.

In fact, the sterane signature of the Chinkeh oils relate the oil accumulation best to a Cretaceous or younger source rock. The percentage of C<sub>28</sub> (relative to C<sub>27</sub> and C<sub>29</sub>) steranes in crude oils have been found to increase through geological time due to the increased diversification of phytoplankton assemblages (Grantham and Wakefield, 1988). This is also true for the crude oils from WCSB which show an increasing proportion C<sub>28</sub> steranes from Devonian oils through Triassic and Jurassic oils to Cretaceous oils (Creaney et al., 1991; Fig 3). In the Cretaceous Colorado-sourced oils, the C<sub>27</sub>-C<sub>28</sub>-C<sub>29</sub> steranes are roughly at equal concentrations (Fig 3), similar to the Chinkeh oils from Maxhamish field. Although detailed geochemical investigation still needs to be undertaken on the Cretaceous Garbutt shale for its hydrocarbon signature, prevailing geochemical and geological evidence suggests the Garbutt shale is likely the main source rock for the Chinkeh oil in the Maxhamish field.

## Conclusions

The Chinkeh oil at Maxhamish field in Liard Basin has a 40° API gravity and a low sulfur content of less than 0.1%. Biomarker composition indicates the oil is sourced from marine shale, and was generated at a thermal maturity around 0.8–1.0% Ro. The Devonian and Triassic shales are unlikely to have made any significant contribution to the Chinkeh oil accumulation based on their sharp difference in the distribution of sterane biomarkers. The even or balanced C<sub>27</sub>-C<sub>28</sub>-C<sub>29</sub> sterane carbon number distribution pattern displayed by the Chinkeh oil suggests that its main source rock is of Cretaceous age or younger. Based on current geological and geochemical knowledge, the Cretaceous Garbutt shale overlying the Chinkeh sandstone is likely the main source rock for the Chinkeh oil accumulation at Maxhamish. However, this needs to be confirmed by further geochemical investigation on the Cretaceous Garbutt shale and the Triassic Toad/Grayling shale.

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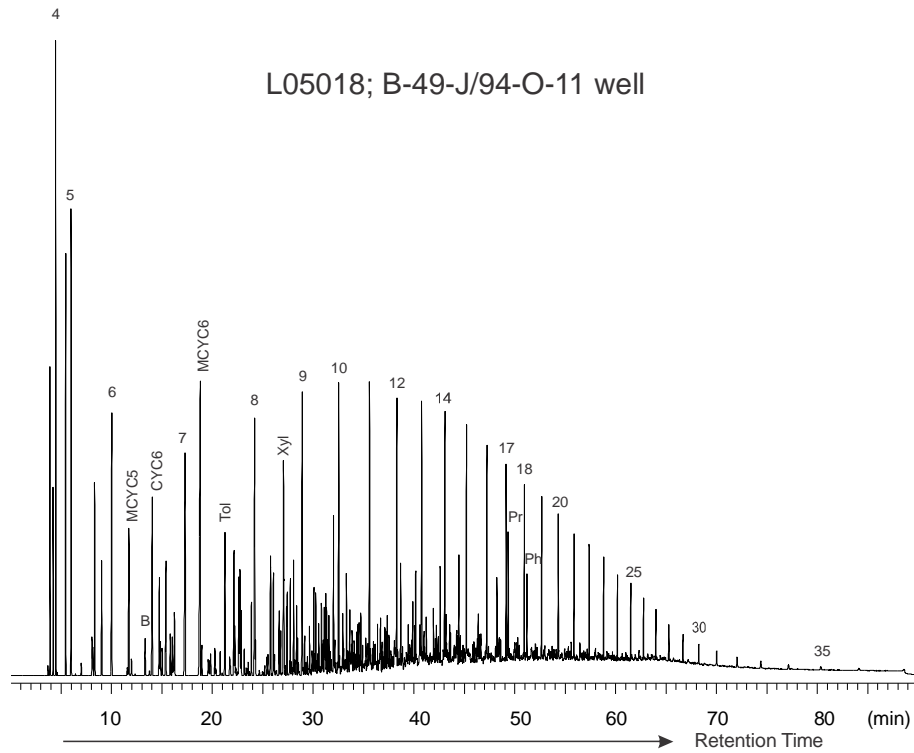


Fig 1. Trace of whole GC analysis showing the total hydrocarbon distribution for a Chinkeh oil sample from the Maxhamish field, Liard Basin. Numbers on the top of selected peaks denote the carbon number of the normal alkanes. MCYC5: methyl cyclopentane; B: benzene; CYC6: cyclohexane; MYC6: methyl cyclohexane; Tol: toluene; xyl: xylene; Pr: pristene; Ph: phytane

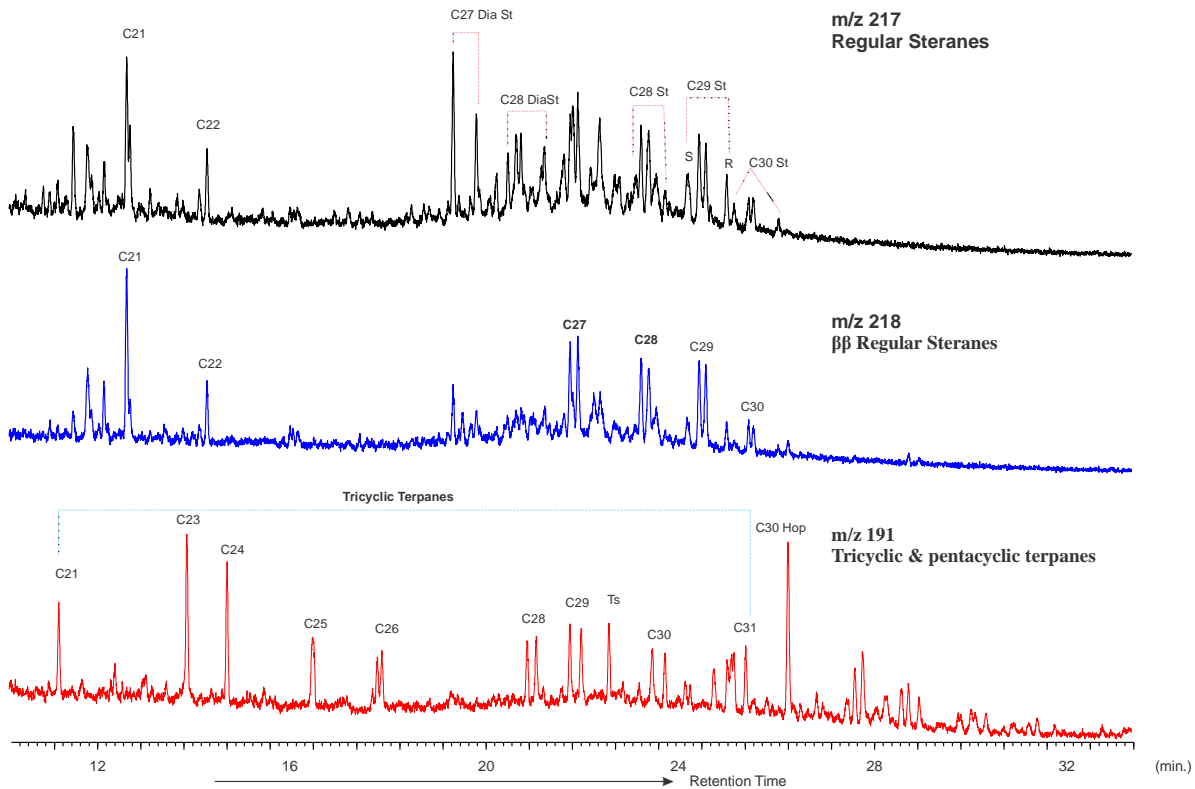


Figure 2. Mass chromatograms of m/z 217, 218 and 191 from GC-MS analysis showing the distributions of steranes and terpanes for a light crude oil sample from well B-49-J/94-O-11 of Maxhamish field, Liard Basin.

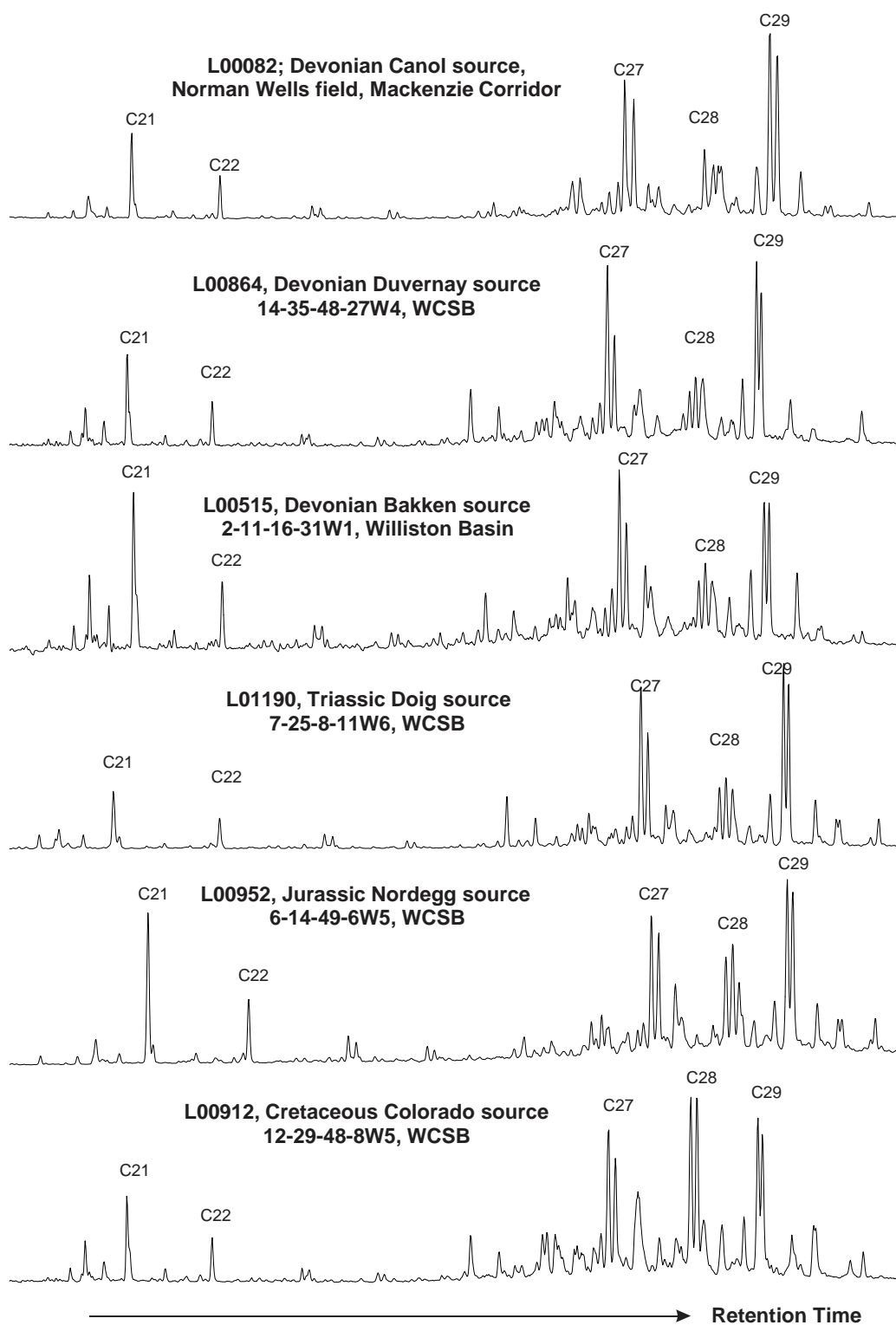


Figure 3. Mass chromatograms  $m/z$  218 showing the distribution of C27-C28-C29 steranes for oils sourced from Devonian Canol shale in Mackenzie Corridor basin, Devonian Duvernay and Bakken, Triassic Doig, Jurassic Nordegg and Cretaceous Colorado shale units in WCSB.