Final report VISTA 2015

Catalytic Conversion of Kerogen

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1. **½ A4 page with a popular presentation of the project (to be written by the scholar)**
   Developing the conversion of alternative hydrocarbon sources to transportation fuels and chemical feedstocks has recently attracted considerable interest to reduce the current over dependence on conventional fossil sources. Kerogen, commonly defined as the insoluble macromolecular organic matter (OM) dispersed in sedimentary rocks, is an unconventional hydrocarbon source, and it is by far the most abundant form of OM on Earth. In particular, its high hydrogen-to-carbon ratio gives the potential to be superior to heavy oil or coal as a source of liquid fuel.
   In the past, the most common production technology is an ex-situ process, i.e., surface mining followed by processing in above-ground retorts. Process temperatures are ca. 500 °C, which converts kerogen to oil in about an hour. This approach has the virtue of simplicity, but requires expensive surface facilities and the disposal of vast quantities of spent rock. Although an alternative in-situ conversion (e.g., piloted by Shell in Colorado, 2005, USA on a period of 3 years) process has captured the industry's attention, it still needs a more energy-efficient way for in-situ conversion of kerogen. Addressing this challenge is the purpose of this project, where catalysis, the core of the activity, is a key technology. This project is to be focused on fundamental understanding of kerogen upgrading by thermal and catalytic processes.

2. **Have there been any changes in the objective/goals during the project period? Did you achieve what was promised in the project description? (to be written by the scholar)**
   The main goal of this project at the beginning is to achieve hydrothermal catalytic conversion of kerogen in the presence of hydrogen. Unfortunately, there has no relevant literature about catalytic process. On the basis of some preliminary experimental results and discussion with Statoil, this goal was modified to fundamental understanding of kerogen upgrading by thermal and catalytic processes. It principally involves three aspects: i) Characterization of raw oil shale and its thermal upgrading; ii) separation, characterization and thermal upgrading of bitumen and kerogen; iii) catalytic upgrading of kerogen to fuels.
   We have developed a comprehensive characterization approach to unravel physico-chemical properties (e.g., crystal phase composition, textural properties, as well as

nature and thermal behavior of organic matters) of raw oil shale from Green River Formation. Bitumen and kerogen were separated, and their natures (e.g., structural properties, n_C/n_H and kerogen type) and thermal behaviors (e.g., activation energy and product distribution) were systematically investigated. Several catalysts such as mineral acids, metal oxides and transition metal chlorides were immobilized onto kerogen surface, which was tested by TGA, EGA-MS and Py-GC/MS techniques. Finally, the catalyst structure-performance relationship was established. The modified research goal has been achieved, and new insights revealed here could guide rational design and optimization of catalysts for kerogen upgrading and catalytic processes.

3. Publications (scholar)

(1) Upgrading of Green River oil shale: Thermal transformation of bitumen and kerogen to fuels by TGA and Py-GC/MS. Xuezhi Duan, Isaac Yeboah, Jia Yang, Erling Rytter, De Chen. *In preparation*.

(2) Comprehensive characterization of Green River oil shale and its thermal upgrading to fuels. Xuezhi Duan, Isaac Yeboah, Cornelis van der Wijst, Erling Rytter, De Chen. *In preparation*.

(3) Catalytic upgrading of kerogen from Green River formation by TGA-DSC, EGA-MS and Py-GC/MS. Xuezhi Duan, Isaac Yeboah, Erling Rytter, De Chen. *In preparation*.

4. Reflections on continuation of the project (to be written by the project director)

(1) Our recent findings reveal that transition metal chlorides are more active for kerogen upgrading. Optimization of these catalysts and reaction conditions, and quantitative analyses of products need to be done.

(2) All our current studies have been performed in some characterization equipments. Considering practical application of this catalytic system, fixed-bed catalytic pyrolysis testing should be carried out to explore its feasibility. Furthermore, we also study effects of hydrogen, water and other solvents, which have been reported to affect the upgrading of other hydrocarbons.

(3) Hydrothermal catalytic process is a promising way for biomass conversion. It is highly desirable to probe whether hydrothermal catalytic method is effective for kerogen conversion and how does it work.

All of above interesting topics are on-going in our group.