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APPLICATION OF PETROLEUM BIOMARKERS FOR CHARACTERIZATION AND SOURCE IDENTIFICATION OF CRUDE OIL

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Abstract

The formation of crude oil occurred many millions of years ago from decaying plants and animals. Sediment and rock covered the organic material creating an anaerobic environment that eventually, under temperature and pressure conditions, formed crude oil. Crude oils from various regions differ in the plant and animal source materials, as well as the time, temperature, and pressure conditions that occurred during formation. Therefore, each crude oil has a unique fingerprint that can potentially be determined using biomarkers.

Biomarkers are one of the most important hydrocarbon groups in petroleum for chemical fingerprinting, they are complex molecules derived from formerly living organisms. The biomarkers found in crude oils, rocks, and sediments are stable and show little or no changes in structures from their parent organic molecules, biogenic precursors (e.g., bacteriohopanetrol, sterols), in living organisms, and thus carry information about the nature, source, type, geological conditions, and thermal history of these organisms.

Biomarkers can be detected in low quantities (ppm and subppm level) in the presence of a wide variety of other types of petroleum hydrocarbons using the gas chromatography/mass spectrometry (GC/MS). Relative to other hydrocarbon groups such as alkanes and most aromatic compounds, biomarkers, hopanes and steranes are also more biodegradation-resistant hydrocarbon compounds.

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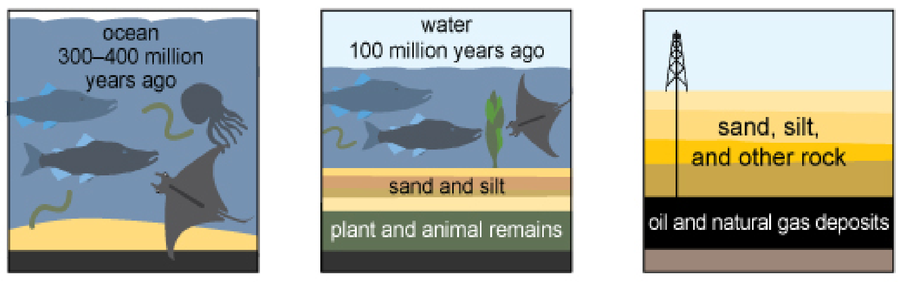
Petroleum and natural gas formation

Tiny marine plants and animals died and were buried on the ocean floor. Over time, the marine plants and animals were covered by layers of silt and sand.

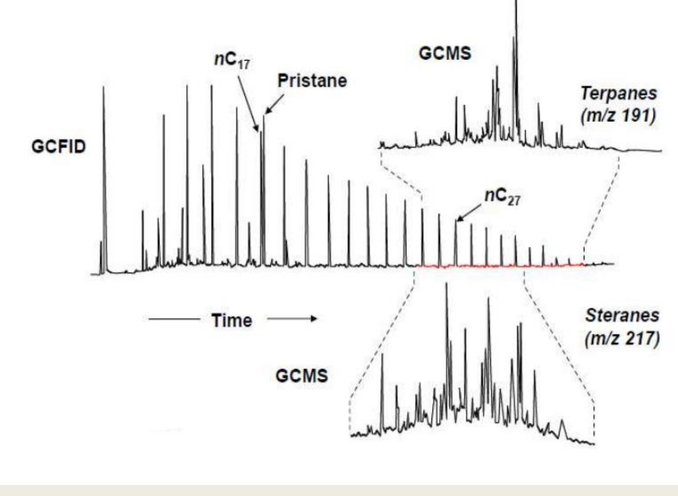
Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned the remains into oil and natural gas.

Today, we drill down through layers of sand, silt, and rock to reach the rock formations that contain oil and natural gas deposits.

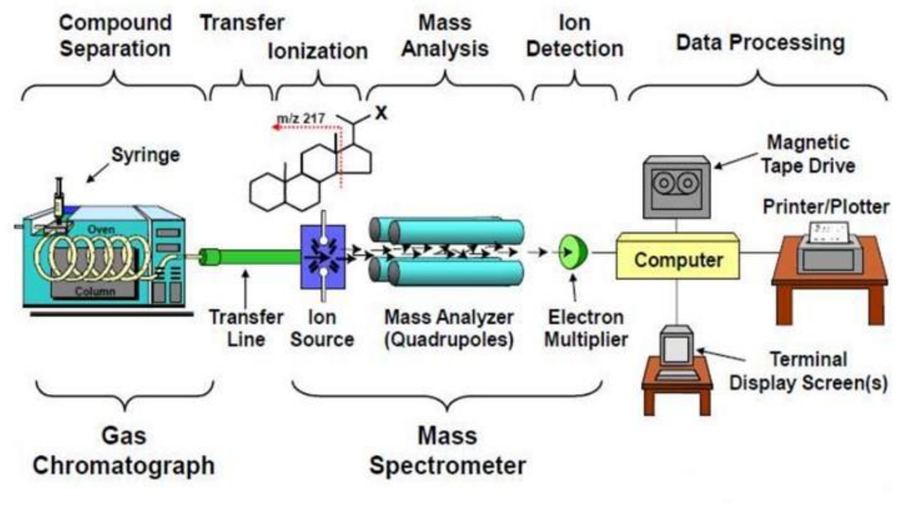


Source: Adapted from National Energy Education Development Project (public domain)

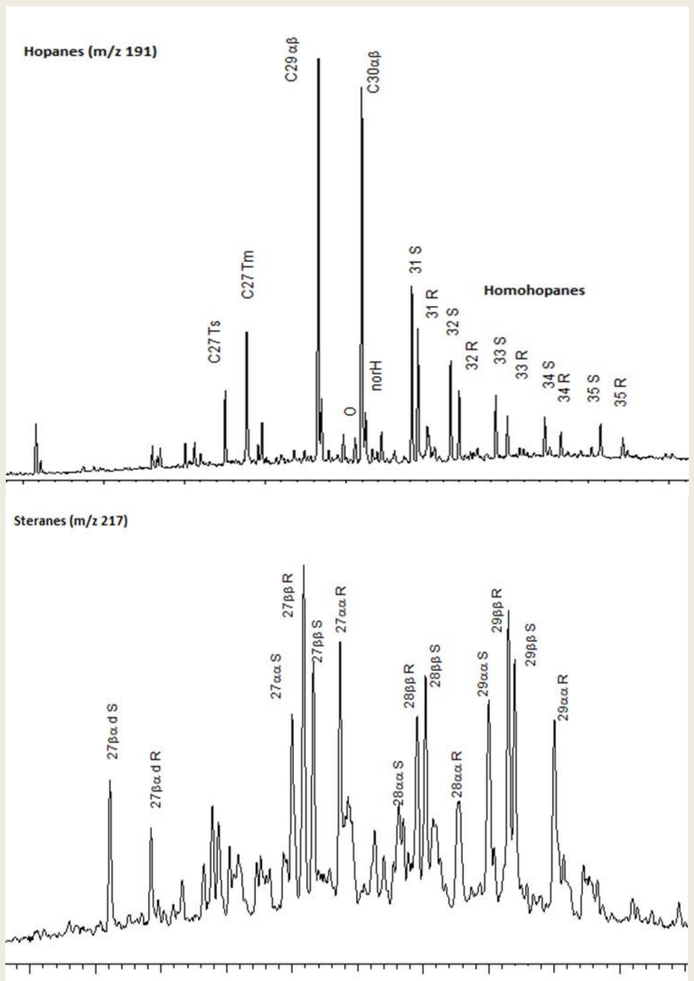
Petroleum Originates From Organic-Rich Source Rocks



Selected Ion Monitoring GCMS: Characteristic Fragments



Mass Chromatograms Show Peaks Not Visible on GC



Peak	Compound
C27Ts	18α(H)-22,29,30-trisnorneohopane (Ts)
C27Tm	17α(H)-22,29,30-trisnorhopane (Tm)
C29αβ	17α(H)-21b(H)-30-norhopane
O	17α(H)-oleanane
C30αβ	17α(H)-21b(H)-hopane
norH	17α(H)-30-nor-29-homohopane
31S, 31R	17α(H)-21b(H)-30-homohopane (22S, 22R)
32S, 32R	17α(H)-21β(H)-30-bishomohopane (22S, 22R)
33S, 33R	17α(H)-21β(H)-30-trishomohopane (22S, 22R)
34S, 34R	17α(H)-21β(H)-30-tetrakishomohopane (22S, 22R)
35S, 35R	17α(H)-21β(H)-30-pentakishomohopane (22S, 22R)
27βα S d	13β(H)-17α(H)-diacholestane (20S)
27βα R d	13β(H)-17α(H)-diacholestane (20R)
27αα S	5α(H), 14α(H), 17α (H)-cholestane (20S)
27ββ R	5α(H), 14β(H), 17β (H)-cholestane (20R)
27ββ S	5α(H), 14β(H), 17β (H)-cholestane (20S)
27αα R	5α(H), 14α(H), 17α (H)-cholestane (20R)
28αα S	5α(H), 14α(H), 17α(H), 24- methyl-cholestane (20S)
28ββ R	5α(H), 14β(H), 17β(H), 24- methyl-cholestane (20R)
28bb S	5α(H), 14β(H), 17β(H), 24- methyl-cholestane (20S)
28αα R	5α(H), 14α(H), 17α(H), 24- methyl-cholestane (20R)
29αα S	5α(H), 14α(H), 17α(H), 24- ethyl-cholestane (20S)
29ββ R	5α(H), 14β(H), 17β(H), 24- ethyl-cholestane (20R)
29ββ S	5α(H), 14β(H), 17β(H), 24- ethyl-cholestane (20S)
29αα R	5α(H), 14α(H), 17α(H), 24- ethyl-cholestane (20R)

Hopanes (m/z 191) distribution

Hopanes belong to the most important petroleum hydrocarbons that retain the characteristic structure of the original biological compounds. Mass fragmentogram at m/z=191 can be used to detect hopanes in the saturate hydrocarbon fraction. The homohopanes (C^{31} to C_{35}) are believed to be derived from bacteriopolyhopanol of prokaryotic cell membrane. Distribution of homohopanes can be used as an indicator of the associated organic matter type, as it can also be used to evaluate the oxic/anoxic conditions of source during and immediately after deposition of the source sediments.

Steranes (m/z 217) distribution

The distribution of steranes is best studied on GC/MS by monitoring the ion m/z=217 which is a characteristic fragment in the sterane series. It is agreed that the relative amounts of C27-C29 steranes can be used to give indication of source differences. For example, predominance of C28, C29 and C30 steranes indicate an origin of the oils derived mainly from mixed terrestrial and marine organic sources, while oils show slightly low abundance of C28 and C29 and relatively higher concentrations of C27 steranes indicate more input of marine organic source.