Oil Families Affiliation Study

in Western Greece Oils and Core Extracts

School of Mineral Resources Engineering

Petroleum Engineering Masters Program

Technical University of Crete

Foteine Dimitracopoulos

SUPERVISOR

Prof. Nikos Pasadakis

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ABSTRACT

Western Greece has long been commonly known to be a region in which hydrocarbons are present. It was recorded during the Classical Period of ancient Greece and the Roman Empire that there are locations in western Greece at which oil wells out of the earth; these were marked as significant locations to obtain the hydrocarbons as a valuable resource. Despite this common knowledge, hydrocarbon exploration in Greece did not begin in earnest until the last century. Since then, only three commercial oil and gas reservoirs were discovered – the Kavala and Prinos oil fields in the Aegean Sea, and the West Katakolo oil field in the western Peloponnese. Western Greece continues to be a region of great interest to the commercial sector due to the geological history and structural geology of the three major zones in the area: the Gavrovo zone, the Pre-Apulian zone, and the Ionian zone (the latter of which is considered to have the greatest potential for an oil and gas reservoir). However, comparatively few explorations have been conducted as the understanding of the hydrocarbons continues to expand.

This thesis focuses primarily on two major elements: firstly, to create a database that contains all of the current data available regarding hydrocarbons in western Greece; and secondly, to perform an analysis on the available data. The database is meant to be a resource that can be added to over time as research and hydrocarbon exploration continue in western Greece. The analysis conducted using the data compiled in the database was done using the MATLAB programming software. Hierarchical clustering methods were also utilized in the data analysis process. This analysis was used to determine information such as the kerogen type, maturity, source dependability, and potential for hydrocarbon generation of the samples, as well as the possible original type of depositional environment. The objective of this analysis is to determine whether or not there could be a relationship among the available data, which could prove to be invaluable in future explorations.

The results indicated that the oldest samples from more consolidated formations such as the Vigla Shales and the Posidonia Beds are most likely to generate good quality oil-prone Type II kerogens, while the younger formations are more likely to be oil-or-gas-prone Type III and Type IV kerogens with less potential to produce viable hydrocarbons for commercial use. In addition, analysis of the alkanes data on the individual components of the samples from C_{14} to C_{35} indicated the possible origins of the samples. Bar charts and a dendrogram were created to illustrate the possible relationship among these samples. The resulting figures indicated the likelihood of the existence of two major oil families, which could have significant implications for future research. It must be emphasized that in order to confirm the relationship of the data, more information must be added to the database as research on hydrocarbons in western Greece continues.

ΠΕΡΙΛΗΨΗ

Η Δυτική Ελλάδα αποτελεί μια γνωστή περιοχή υδρογονανθράκων. Κατά τη διάρκεια της Κλασσικής Περιόδου της Αρχαίας Ελλάδας και της περιόδου της Ρωμαϊκής Αυτοκρατορίας υπήρχαν περιοχές στις οποίες ανέβλυζε πετρέλαιο, επομένως εθεωρούντο σημαντικές για τη μελέτη υδρογονανθράκων και την παραγωγή πετρελαίου. Παρά το γεγονός ότι η ύπαρξη υδρογονανθράκων ήταν γνωστή, οι έρευνες για υδρογονάνθρακες δεν είχαν αρχίσει εντατικά μέχρι τον περασμένο αιώνα. Από την εποχή εκείνη, μόνο τρία κοιτάσματα υδρογονανθράκων ανακαλύφθηκαν – τα κοιτάσματα της Καβάλας και του Πρίνου στο Αιγαίο, καθώς και το κοίτασμα στο Δυτικό Κατάκολο στη Δυτική Πελοπόννησο. Η Δυτική Ελλάδα εξακολουθεί να είναι περιοχή με μεγάλο εμπορικό ενδιαφέρον λόγο της γεωλογικής ιστορίας και της δομικής γεωλογίας των τριών σημαντικών ζωνών – οι Ζώνες Gavrovo, Pre-Apulian και Ionian (η τελευταία από τις οποίες θεωρείται να έχει τη πιο μεγάλη δυνατότητα για ταμιευτήρες πετρελαίου και φυσικού αερίου). Μολονότι οι γνώσεις για τις έρευνες κοιτασμάτων πετρελαίων έχουν επεκταθεί σημαντικά, πολύ λίγες έρευνες έχουν γίνει σε αυτές τις περιοχές.

Η εργασία αυτή εστιάζει κυρίως σε δύο βασικά στοιχεία. Αρχικά, τη δημιουργία μίας βάσης δεδομένων περιέχοντας όλες τις μέχρι στιγμής διαθέσιμες πληροφορίες σχετικά με τους υδρογονάνθρακες στη Δυτική Ελλάδα, και στη συνέχεια την ανάλυσή τους. Η βάση δεδομένων αποτελεί μια βάση στοιχείων που μπορεί να επεκταθεί, ως αποτέλεσμα της εξερεύνησης νέων κοιτασμάτων στη Δυτική Ελλάδα. Η μέθοδος της ανάλυσης συστάδων (ιεραρχικής ταξινόμησης) χρησιμοποιήθηκε για την ανάλυση των δεδομένων, με τη χρήση του MATLAB λογισμικού. Μέσω της ανάλυσης καθορίστηκαν πληροφορίες όπως το είδος του κηρογόνου, η ωριμότητα, το είδος των μητρικών πετρωμάτων, η δυνατότητα δημιουργίας υδρογονανθράκων, καθώς επίσης και ο πιθανός καθορισμός του περβάλλοντος εναπόθεσης. Στόχος της ανάλυσης αποτελεί η διαπίστωση ύπαρξης κάποιας σχέσης μεταξύ των υπαρχόντων δεδομένων, που θα μπορούσε να είναι πολύτιμη σε μελλοντικές εξερευνήσεις.

Τα αποτελέσματα δίχνουν ότι τα παλαιότερα δείγματα από συμπαγείς σχηματισμούς, όπως για παράδειγμα τα Vigla Shales και το Posidonia Beds είναι πιο πιθανά να δημιουργήσουν υψηλής ποιότητας Τύπου II κηρογόνο, ενώ οι νεότεροι σχηματισμοί είναι πιθανόν να δίνουν Τύπου III και Τύπου IV κηρογόνα με χαμηλότερη ποιότητα υδρογονανθράκων. Επίσης, η ανάλυση των δειγμάτων αλκανίων των δειγμάτων από C_{14} έως C_{35} υποδηλώνει την προέλευση των δειγμάτων. Χρησιμοποιήθηκαν ραβδογράμματα και δενδρογράμματα για να απεικονίσουν τη πιθανή σχέση μεταξύ των δειγμάτων. Τα προκύπτοντα στοιχεία δείχνουν την πιθανότητα ύπαρξης δύο κύριων οικογενειών πετρελαίου, που θα μπορούσαν να έχουν πολύ σημαντική επιρροή σε μελλοντικές έρευνες. Θα πρέπει να τονιστεί ότι καθώς η έρευνα για υδρογονάνθρακες συνεχίζεται στη Δυτική Ελλάδα, περισσότερες πληροφορίες θα πρέπει να προστεθούν στη βάση δεδομένων προκειμένου να επιβεβαιωθεί η μεταξύ τους σχέση.

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Introduction

Investigations of oil seepages in Greece have been conducted since the early 20th century, but people have been aware of the presence of hydrocarbons in Greece since ancient times. Herodotus writes in *The Histories* that he has personally seen "pitch brought up out of a pool of water [in Zakynthos]" (Herodotus. *The Histories*, IV. v195) and that the pitch "has the smell of asphalt" and is better in quality compared to pitch from other regions. Furthermore, this description of the hydrocarbons indicates the presence of bituminous material. There are currently several active oil and gas producing sites in Greece at the Kavala and Prinos oil fields in the Aegean Sea, as well as the West Katakolo field currently in development in western Greece, as shown in Figure 1 (Lie 2014).

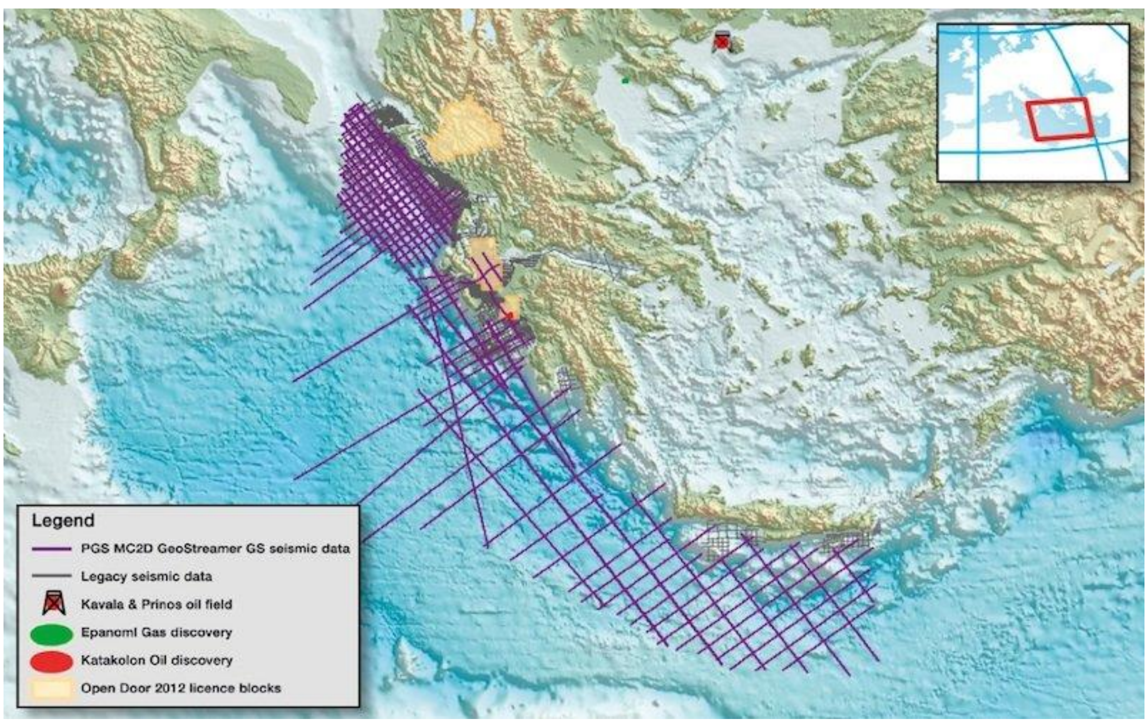

Figure 1 - Map of Active Oil Fields and Seismic Lines (Image from Lie 2014)

However, the region of western Greece and the Ionian Sea have remained mostly unexplored, despite the clear presence of oils at the surface (Maravelis *et al*., 2013). This region has long been of particular interest due to the many seepages in the area, such as the Keri oil seep on Zakynthos and the oil seeps in Epirus (Zelilidis *et al*., 2015). Onshore explorations have been sporadically explored up to the 1960s, but more thorough studies were conducted in the 1970s

(Zelilidis *et al*., 2015). In the mid 1980's, Chevron conducted a study on the source correlation of biodegraded crude oils from specific locations in western Greece to investigate the degree of biodegradation (Seifert *et al*., 1984). Shortly afterwards, the U.S. Geological Survey and the Public Petroleum Corporation of Greece (DEP) – a company dedicated to oil exploration in Greece – combined resources to work on researching the petroleum geochemistry and source rock potential of western Greece (Palacas *et al*., 1986). In the years since, Greece has approved of major explorations – more than one hundred wells were drilled, and thousands of kilometers of seismic data was collected (Zelilidis *et al*., 2015). Only one oilfield was discovered in 1982 in West Katakolo, which produces hydrocarbons that date back to the Upper Cretaceous through the Paleocene and Eocene (Zelilidis *et al*., 2015). There are two wells that have been drilled offshore in this region, which together produce approximately 1,500 barrels of oil per day and 20 million standard cubic feet of gas per day (Karakitsios 2013). Despite these studies and the success of the West Katakolo oil field, western Greece still has potential for the discovery of new oil and gas reservoirs, as some of the wells drilled yielded optimistic results for hydrocarbons (Maravelis *et al*., 2013). The samples retrieved from these wells indicated a significant presence of oil and gas shows, which in turn implies that there is a viable source rock in western Greece (Maravelis *et al*., 2013).

An oil show can be described as liquid oil or solid tar that has accumulated at the surface. They are useful but not necessarily required for oil exploration, which depends greatly on the geological history of the region in question. Oil shows can be defined as either direct shows or as indirect shows. For direct shows, there is an ongoing supply of hydrocarbons exposed at the surface, whereas indirect shows consist of hydrocarbons that have heavier components and have been greatly altered by weathering, decomposition, oxidation, and biodegradation (Rigakis *et al*., 2007). Indirect oil shows can potentially form tar sands consisting of a mixture of sand, clay, water, and altered hydrocarbons – these can easily fill faults and porous rocks. Although the presence of oil shows is encouraging, it does not necessarily indicate that there is a reservoir directly beneath the location of the oil show, as they can result from migration either directly from the source rock beneath the surface, or as leakage from a reservoir (Rigakis *et al*., 2007). In addition to oil shows with evidence for liquid and solid hydrocarbons in western Greece, there are a number of indications of gaseous seepage found in oil wells, which adds to the significance of investigating the region (Rigakis *et al*., 2007).

Despite the encouraging presence of surface oil shows, the existence of a reservoir depends greatly on the geological history of the region. In order for there to exist a reservoir of potential hydrocarbons, certain conditions must be met: there must be a source rock, a reservoir rock, a seal, and a trap. Figure 2 below is an example of a reservoir with more complicated geometry; one of infinite possible situations according to the local geology.

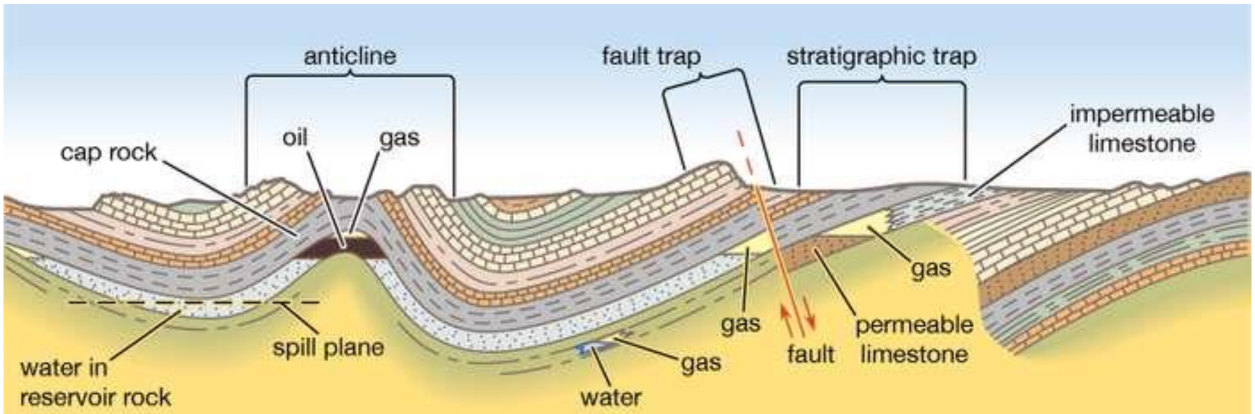

Figure 2 - Example of Petroleum Reservoir Structure (image from Riva 2019)

The source rock is the rock from which hydrocarbons originate – these tend to be sedimentary rocks that contain enough organic matter that under specific conditions of pressure and temperature will produce petroleum (Gluyas and Swarbrick, 2004). In order for there to be enough organic matter to eventually yield petroleum, the environment at the time of deposition must be rich in organic matter and allow for rapid layering of sediments over the organic matter, and/or have anoxic conditions. Environments that meet these criteria include swamps, shallow seas, and lakes (Gluyas and Swarbrick, 2004). The deposited organic matter can then be converted to crude oil and natural gas at three different stages. The first is diagenesis, which occurs at depths of several hundred meters to 1,000 meters and have a temperature up to 150 degrees Fahrenheit; this stage usually results in biochemical methane and kerogen. The second stage is catagenesis, which occurs at a depth between 1,000 and 4,000 meters, and have a temperature between 150 to 300 degrees Fahrenheit. This stage results in the production of the majority of liquid hydrocarbons and wet gas. The final stage is metagenesis, which occurs at depths greater than 4,000 meters, has temperatures between 300 to 400 degrees Fahrenheit and generates dry gas (Dandekar 2013).

The reservoir rock that contains the petroleum is usually porous and permeable – rocks with these characteristics are sandstones and carbonates (Gluyas and Swarbrick, 2004). Due to their low density, oil and gas tend to rise to the surface and must be able to travel through the rock; eventually the hydrocarbons will reach the surface, unless there is a seal to obstruct the migration. Although not infallible, a good seal will trap the hydrocarbons beneath the surface. The most effective seals are rocks with low permeability, such as fine-grained rocks like mudstone or shale, cemented limestones, cherts, anhydrites, or salts (Gluyas and Swarbrick, 2004). Seals can follow faults and fractures, which can complicate the geometry of the reservoir and cause difficulties in accessing the hydrocarbons from the surface. Hydrocarbons that manage to reach the surface are heavily altered and can be rendered next to useless depending on the degree of degradation. Thus, it is crucial to understand the geology of the region in question to determine whether or not the features required for a hydrocarbon reservoir to exist are present.

Geological Setting and Tectonic History

The geology of western Greece is recognized by highly complex structural and stratigraphic characteristics caused by the extensive tectonic activity of ocean-continent subduction and continent-continent collision systems (Maravelis *et al.*, 2015). This activity consequently formed the Hellenide Fold and Thrust Belt (FTB) in western Greece, which continues to have high seismic activity and contributes to the complex geology of the area (Maravelis *et al*., 2015, Rigakis *et al*., 2007). The Hellenides are partitioned into three geotectonic zones based on varying formation evolution and past tectonic activity. From west to east they are: the Pre-Apulian, Ionian, and Gavrovo zones, as seen in Figure 3 below (Palacas *et al*., 1986). The following Figure 4 focuses only on western Greece and illustrates the locations of the zones more clearly.

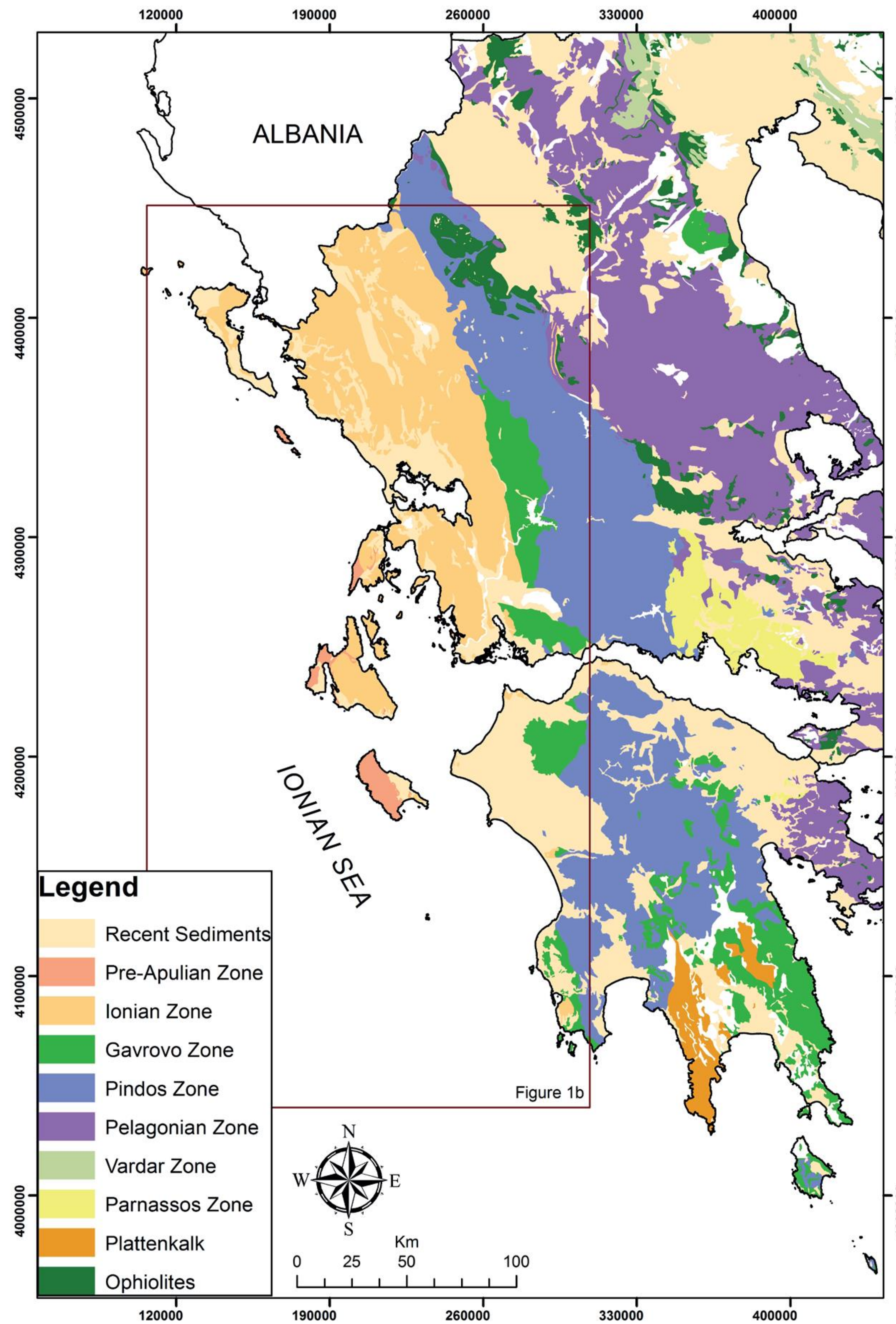

Figure 3 - Geological Map of the Zones in Greece, taken from Zelilidis et al., 2015)

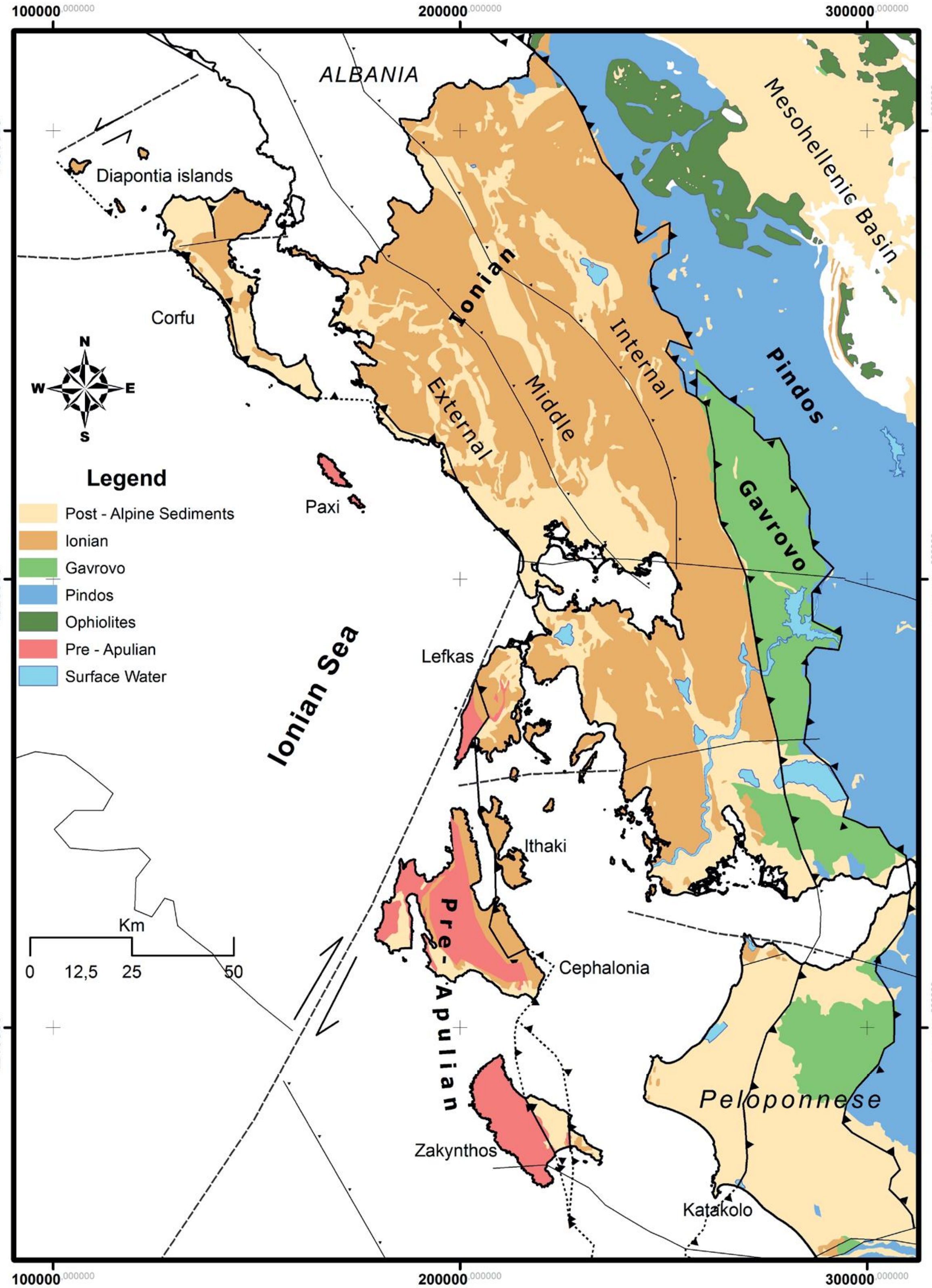

Figure 4 - Geological Map of Zones in Western Greece, taken from Zelilidis et al., 2015

The Gavrovo zone consists of carbonates that date back to shallow marine environments of late Cretaceous to Eocene age, as well as flysch that dates back to the late Eocene to Oligocene (Kamberis *et al*., 2000). This zone outcrops on the Skolis mountain and surrounding regions in the northwestern Peloponnese and borders the Ionian zone (see Figures 3 and 4). The Gavrovo zone exhibits a large number of thrust faults which formed after the late Oligocene, since the flysch conglomerates were settled before the faulting (Kamberis *et al*., 2000). In addition, extensive analysis of the area indicated that the Gavrovo zone is heavily affected by compressional tectonics (Kamberis *et al*., 2000). Figure 5 below is a cross section of the Gavrovo zone and cuts through the Skolis mountain.

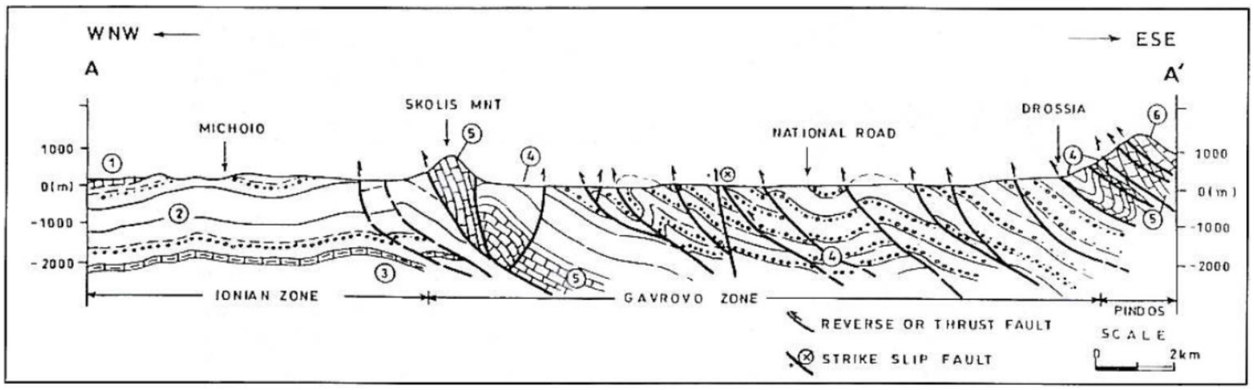

Figure 5 - Cross Section Through the Skolis Mountains, taken from Kamberis et al., 2000

The Pre-Apulian zone consists of Mesozoic carbonates which transition to Miocene marlstone, sandstone, and mudstone (Maravelis *et al*., 2015). The Pre-Apulian zone – also known as the Paxos zone – is the external part of the Hellenides FTB and like the Gavrovo zone, is characterized by a platform with tectonic deformation, such as extension, collision, flexural subsidence, and rotation (Karakitsios 2013). The order of deposition in this zone starts with Triassic limestone, followed by Jurassic limestones and anhydrites through the Cretaceous. Next, pelagic limestones formed in the Paleogene, subsequently followed by marly limestone and marine marls and sands in the Neogene and Quaternary, respectively (Karakitsios 2013). Figure 6, shown below, is a stratigraphic column of the formations found in the Pre-Apulian zone. Pre-Apulian structures outcrop on Zakynthos and Kefalonia islands, which indicate the type of tectonic movement that occurred during the Neogene and Quaternary periods. Observations of these structures show that thrust fault activity occurred during the late Pliocene and Pleistocene (Karakitsios 2013).

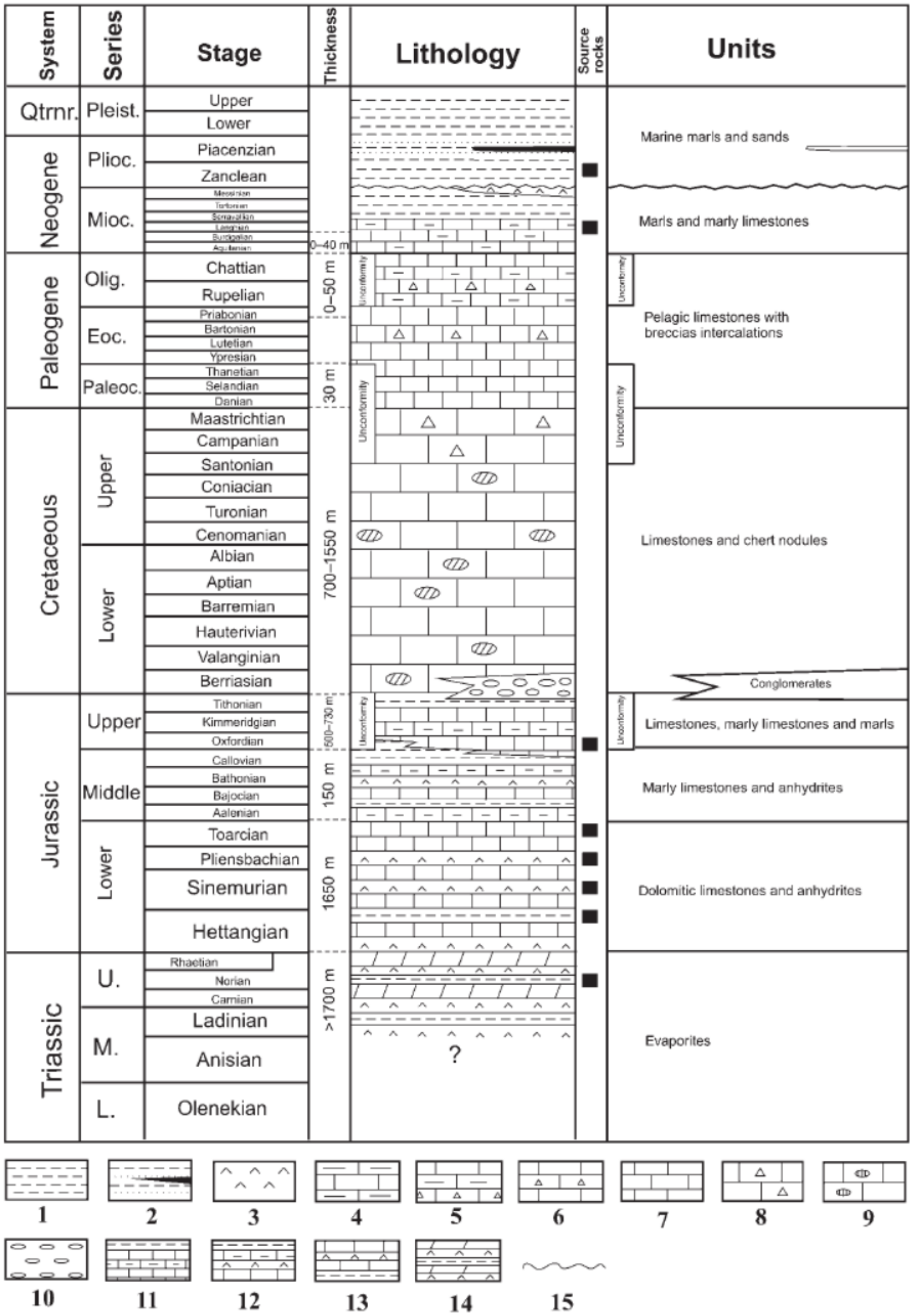

Figure 6 - Stratigraphic Column of the Pre-Apulian Zone, taken from Karakitsios 2013

The Ionian zone has been extensively studied and is the focus of many oil exploration projects. This zone includes rocks that range from the Triassic to the Oligocene; more specifically, Triassic evaporites followed by carbonates from the Jurassic to the Eocene, with some chert and shale overlain by Oligocene flysch carbonates (Rigakis *et al.*, 1998). Figure 7 below is the stratigraphic column for formations found in the Ionian zone.

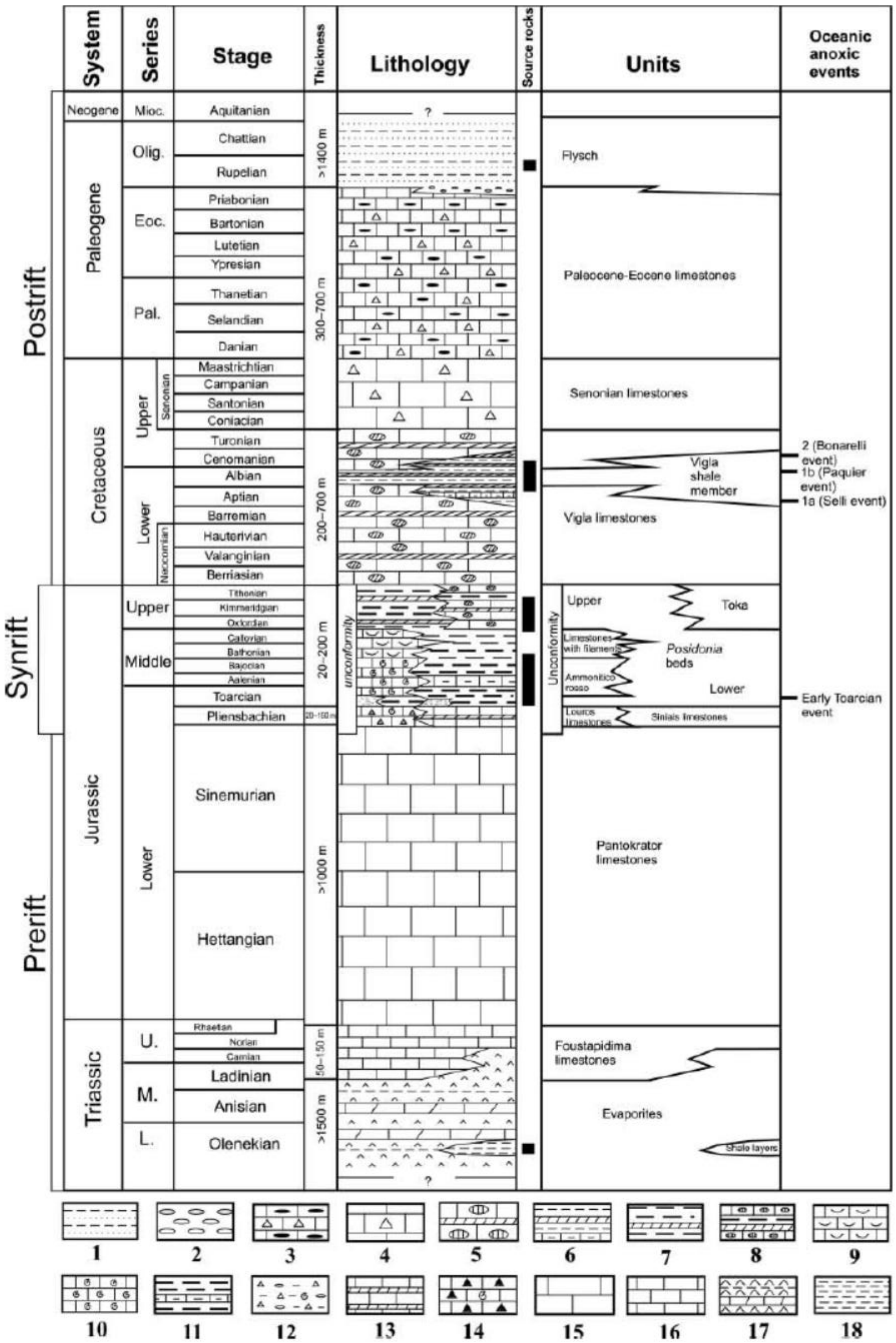

Figure 7 - Stratigraphic Column of the Ionian Zone, taken from Karakitsios 2013

As with the Gavrovo and Pre-Apulian zones, the Ionian zone exhibits some characteristics of tectonic activity, including fold and thrust features (Maravelis *et al*., 2013). However, the formation of this zone began with a submarine basin that separated the Pre-Apulian zone in the west and the Gavrovo zone in the east (Rallakis *et al*., 2013). The Ionian zone can be further separated into three different sequences according to the stages of rifting: the external or pre-rift sequence, the axial or syn-rift sequence, and the internal or post-rift sequence (Rallakis *et al*., 2013, Rigakis *et al*., 1998, Karakitsios 2013**,** Karakitsios 2003, Maravelis *et al*., 2013, Maravelis *et al*., 2015). The formations corresponding to each sequence can be seen in Figure 7 above. The pre-rift sequence is characterized by shallow water, Lower Liassic Limestones (also known as Pantokrator Limestones) that overlie Lower to Mid Triassic evaporites that are more than 2,000 meters thick (Karakitsios 2003), as well as limestones of Ladinian to Rhetian age (also known as Foustapidima Limestones) (Maravelis *et al*., 2015, Maravelis *et al*., 2013). The syn-rift sequence is represented by several key formations, starting with the deposition of Siniais limestones – which are pelagic limestones that date back to the Pliensbachian – and the hemipelagic Louros Limestones (Karakitsios 2013). According to the studies done by Rigakis *et al*., 1998 and Karakitsios 2013, these two limestones correspond to the formation of the Ionian basin as the area subsides and deepens. This activity was followed by an internal differentiation of smaller units with half-graben geometry (Karakitsios 2013). The syn-rift formations become thicker and more wedge-like, and include several formations that have been critical to oil exploration (Zelilidis *et al*., 2015), such as the Pliensbachian Limestones, the Ammonitico Rosso Limestones or Lower Posidonia Beds (Toarcian to Aalenian in age), a limestone formation with filaments (Bajocian to Callovian in age), and Upper Posidonia Beds (late Callovian to Tithonian in age) (Rigakis *et al*., 1998). Further observations noted that the orientation of the formations indicates that some of the deposition was controlled by extension due to the expansion of the Neotethys Ocean and by halokinesis (Karakitsios 2013). The third sequence of the Ionian zone, the post-rift sequence, can be identified by an unconformity at the start of the formation of pelagic limestones (known as Vigla Limestones) from the early Berriasian (Rigakis *et al*., 1998, Maravelis *et al*., 2013, Karakitsios 2013). The Vigla Limestones and the overlying formations cover most of the syn-rift and pre-rift sequences (Rigakis *et al*., 1998, Karakitsios 2013).

A study done by Zelilidis *et al*., 2015 investigates the geological formations of the zones, as seen in the following images. Three cross sections were done along three locations in western

Greece to illustrate the zones beneath the surface. Figure 8 below delineates the locations of these cross sections.

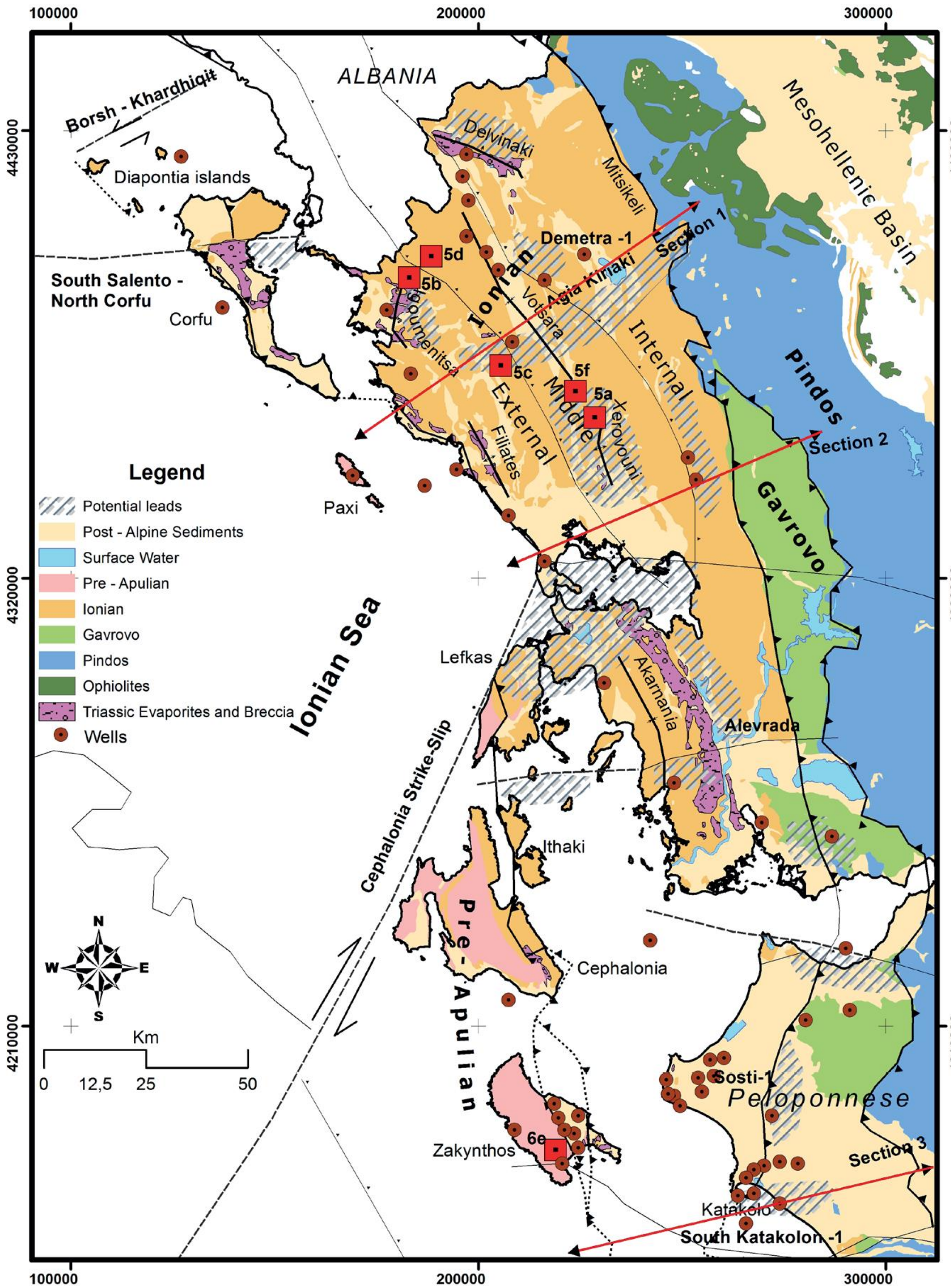

Figure 8 - Map of Western Greece and Albania Showing Locations of the Cross Sections, taken from Zelilidis et al., 2015

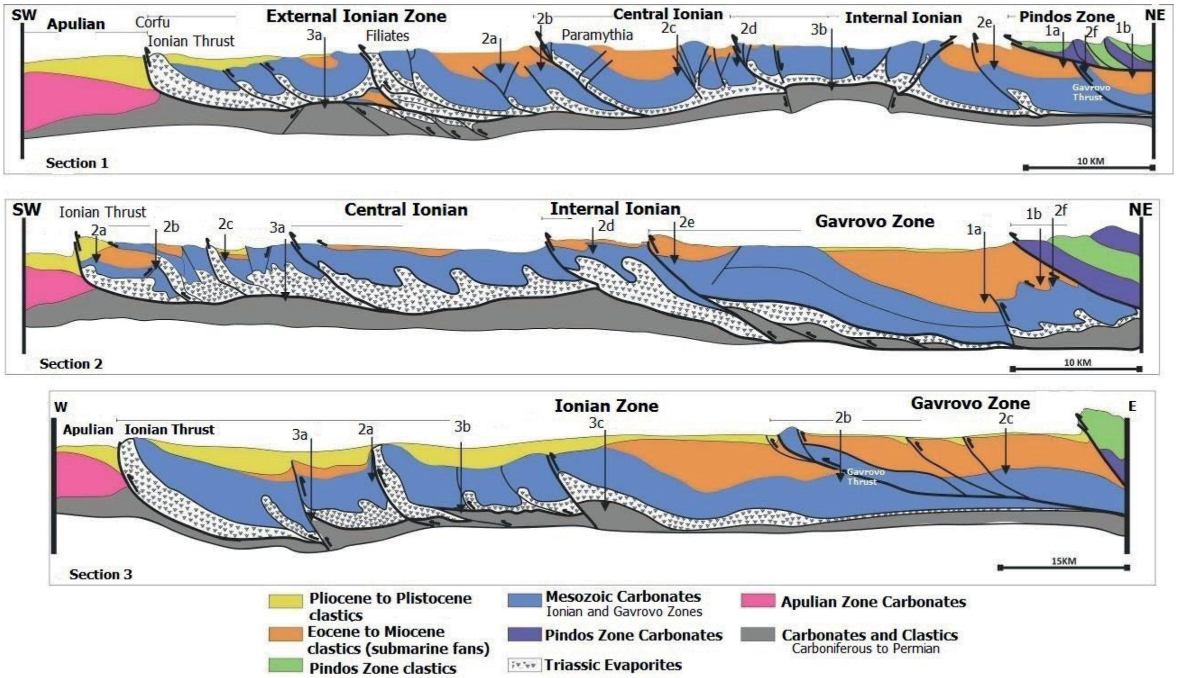

Figure 9 - Cross Sections of the Geological Zones in Western Greece and Albania, taken from Zelilidis et al., 2015

Figure 9 outlines the formations that are believed to be located in these areas according to structural features. These structural features exhibit the appropriate geometry to form a trap that can potentially contain a petroleum reservoir (Zelilidis *et al*., 2015).

Possible Source Rocks

The Ionian zone is the main focus of many oil explorations that have been conducted in the past, due to its location and due to the importance of understanding the geology of a location that has a potential reservoir. Several studies have concentrated on a few key formations in the Ionian zone that have the potential to be a source rock. There are five such formations: The Vigla Shales, the Upper Posidonia Beds, the Lower Posidonia Beds, the marls lining the Ammonitico Rosso Limestones, and the Triassic Shale fragments (Rigakis *et al*., 1998, Karakitsios 2013**,** Karakitsios 2003).

The Vigla Shales are a part of the Vigla Limestones, which were previously mentioned in the description of the post-rift sequence of the Ionian zone. These shales are characterized by limestones and cherts that have dark gray-green or red colored shale interbedding (Rigakis *et al*., 1998). The Vigla Limestones can be identified by thinly bedded gray packstones that alternate with chert and intercalated shale (Rigakis *et al*., 1998).

The Upper Posidonia Beds are Callovian to Tithonian in age and can be identified by yellow-green jasper beds with bituminous cherty clays (Rigakis *et al*., 1998, Karakitsios 2013). This formation can also be identified by a type of pelagic bivalve called *Posidonia* (*Bositra*), and a type of algae called Radiolaria, from the Callovian and Tithonian (Rigakis *et al*., 1998). The Lower Posidonia Beds are considered to be one of the most important source rocks of western Greece (Karakitsios 2013). Identification of this formation is thus crucial for oil explorations. Previous studies describe the Lower Posidonia Beds as well-defined pelagic limestones, marls, and siliceous argillites of some varying thickness (Rigakis *et al*., 1998, Karakitsios 2013). This formation contains a large amount of organic matter and is the main source rock horizon of the Ionian zone (Rigakis *et al*., 1998). This indicates that the environment of deposition was highly anoxic, which was a perfect setting to allow for the preservation of organic matter and the future production of hydrocarbons. As with the Upper Posidonia Beds, the Lower Posidonia Beds can also be identified by *Bositra* and Radiolaria in certain outcrops (Rigakis *et al*., 1998). It must be noted that some sections of the Posidonia Beds are difficult to categorize as either the Upper or Lower Posidonia Beds – thus in these sections they are classified as "undifferentiated Posidonia Beds" (Karakitsios 2013).

The marls that line the Ammonitico Rosso Limestones are characterized by dark gray to blue-green colored foliated marls and marly, slightly siliceous lime wackestones (Rigakis *et al*., 1998). These are rocks are scarce, and can only be found in locations where the Ammonitico Rosso Limestones are clear and well-defined. This formation is Toarcian to Aalenian in age, and correspond to the syn-rift sequence of the Ionian zone (Rigakis *et al*., 1998). Lastly, the Triassic shale fragments can be identified by its high organic matter content. These shale fragments are related to Triassic breccias that are linked to evaporite dissolution collapse breccias (Rigakis *et al*., 1998). They underlie the Ionian tectonic zones, and are compositionally similar to subsurface Ionian evaporites (Karakitsios 2013). The Triassic shale fragments are significant in that they are not source rocks that originated from the Ionian zone (Rigakis *et al*., 1998).

A study done by Karakitsios 2013 presented a series of potential petroleum systems that could exist in the Ionian zone. Figure 10 below shows the possible petroleum systems according to the source rocks from the Triassic, Jurassic, and Cretaceous periods.

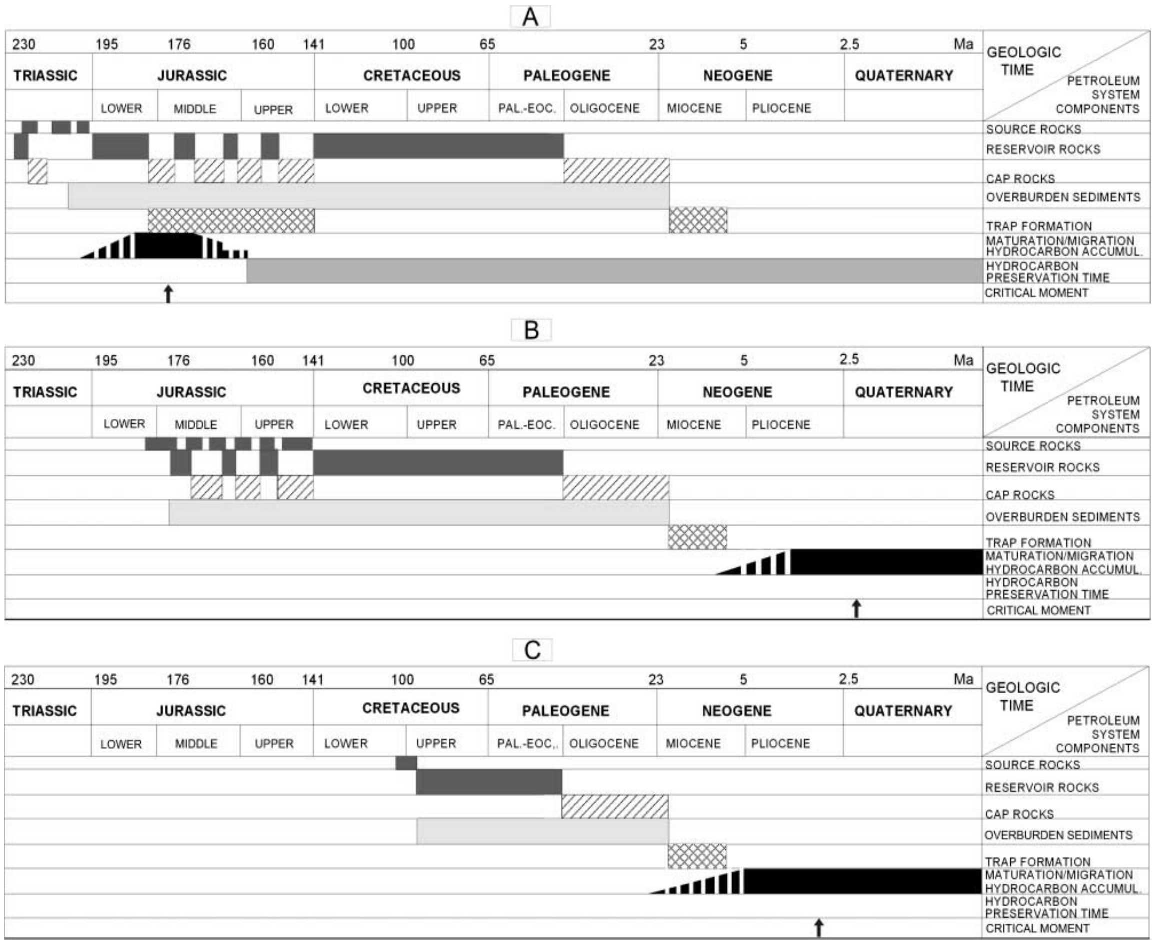

Figure 10 - Potential Petroleum Systems in the Ionian Zone, taken from Karakitsios 2013

As seen in the image above, the blocks identify the possible source rocks, reservoir rocks, and cap rocks that could constitute a reservoir. The darkest blocks represent the migration and accumulation of hydrocarbons over millions of years. According to this study, the best seal formation appears to be the Triassic to Lower Jurassic and Messinian evaporites, as well as Miocene and Pliocene flysch in the Pre-Apulian zone (Karakitsios 2013). Although the identification of potential seals is a good indication of the features of a hydrocarbon trap, it does not necessarily indicate the presence of a hydrocarbon reservoir (Karakitsios 2013). Identification of a potential reservoir or source rock will depend on future studies in the area.

Exploration in Italy and Albania

Previous research on oil exploration has led to the investigation of the geology in both Italy and Albania. There are a series of fold and thrust belts throughout the Adriatic Sea northwest of western Greece which were formed by ocean-continent subduction that has been ongoing since the Late Cretaceous (Zelilidis and Maravelis, 2015). Both the Adriatic and Ionian Seas have a system of foreland basins that potentially contain source rocks, due to their development and formation. Many oil and gas fields have been found in Italy, especially along the eastern coast and in the Adriatic Sea (Zelilidis and Maravelis, 2015). These fields are generally biogenic gas fields that date back to the Pliocene (Zelilidis and Maravelis, 2015). Since the early 20th century, there have been multiple drilling surveys in Italy; there are presently 86 permits and 195 development leases for these active oil and gas fields (Zelilidis and Maravelis, 2015). Figure 11 below shows the locations of oil and gas wells and seeps that have so far been located in the area surrounding the Adriatic Sea.

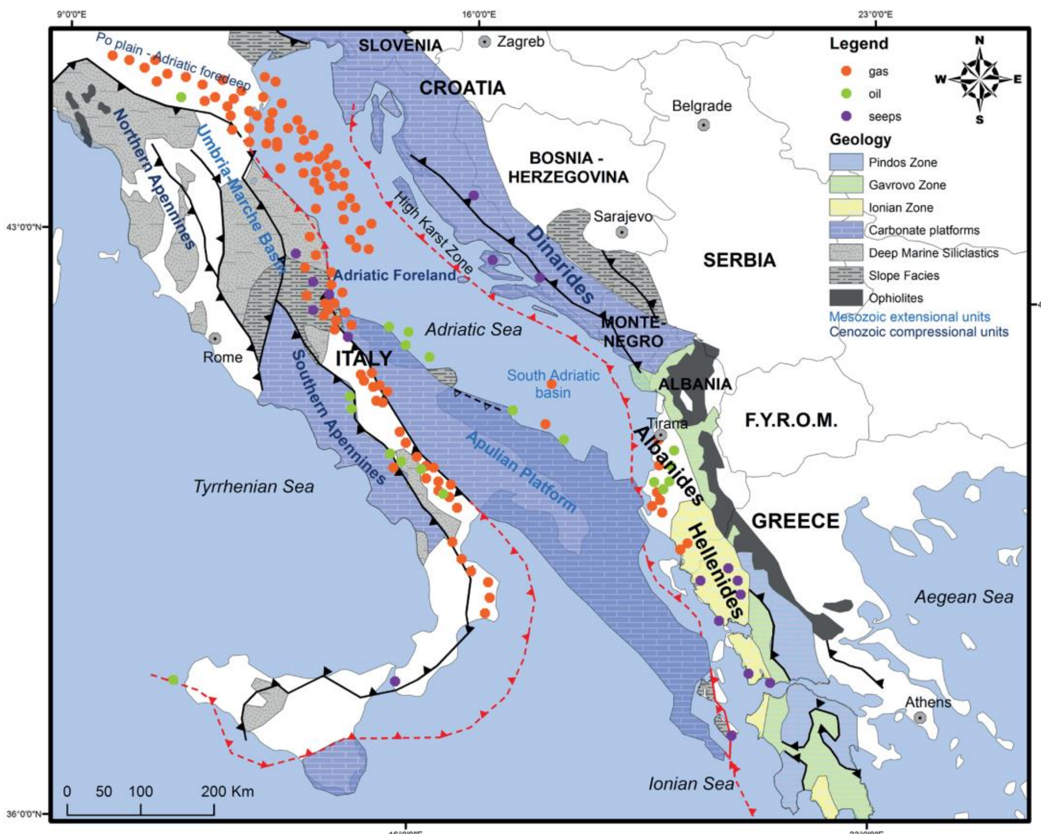

Figure 11 - Map of Oil and Gas Wells in and Around the Adriatic Sea, taken from Zelilidis and Maravelis, 2015

Albania has long been a part of hydrocarbon exploration and commercial activity; it has been an active site since the time of the Roman Empire two thousand years ago (Zelilidis and Maravelis, 2015). The Greek geographer Strabo (63 BCE – 23 CE) wrote about one of the Roman territories, called Apollonia, located in present-day Fier County in Albania. Strabo describes a site in Apollonia called Nymphaeum, which "...is a rock which emits [fire, and below] it are springs flowing with hot water and asphaltus", and "is dug out of a neighbouring hill" (Strabo. *Geography*, VII, chapter 5.8). Modern commercial operations began in 1918, and since then there have been several discoveries of major oil and gas fields (Zelilidis and Maravelis, 2015).

The history of oil exploration and oil discovery in Italy and Albania, as well as geological similarities with structures in western Greece, indicates that there may potentially be sizeable oil and gas fields in western Greece. However, this has not yet been determined, and future studies must be conducted to thoroughly explore the area.

Purpose

The purpose of this research is to examine the geochemical data collected by previous studies done on oils and core extracts in western Greece. A database was created to organize and classify Rock-Eval data, composition of saturated hydrocarbons (alkanes), and data on terpanes, hopanes, and steranes. This database is meant to be a reference that can be edited for future use as more research is conducted on oil exploration and oil studies in western Greece. Further analysis based on the database is focused on the Rock-Eval and saturates data. By performing such an analysis, it is possible to determine if there indeed exists a relationship among the oils studied so far in western Greece.

Methods

This section defines the data used in this research and describes the studies and locations from which the data originates. The data was compiled and organized into a single file as a database for future use; this section also details the process of analysis for the Rock-Eval and saturates data from the database.

Data Acquisition

The data used in this research was gathered from eight studies and compiled into a single file for the purpose of creating a joint database. The papers used are the following (see Works Cited for full citations):

- *Source correlation of biodegraded oils*, Wolfgang K. Seifert, J. Michael Moldowan, Gerard J. Demaison (1984)
- *Geochemical correlation of surface and subsurface oils, western Greece*, J. G. Palacas, D. Monopolis, C. A. Nicolaou, D. E. Anders (1986)
- *The source rock horizons of the Ionian Basin (NW Greece)*, N. Rigakis, V. Karakitsios (1998)
- *The Utility of Oil Shows in the Hydrocarbon Exploration of Western Greece*, N. Rigakis, K. Nikolaou, F. Marnelis, Th. Pakos (2007)
- *Maturity of Dispersed Organic Matter in Bituminous Formations of the Ionian Zone (Epirus Region, NW Greece)*, D. Rallakis, G. Siavalas, R. G. Oskay, D. Tsimiklis, K. Christanis (2013)
- *Stratigraphic evolution and source rock potential of a Lower Oligocene to Lower-Middle Miocene continental slope system, Hellenic Fold and Thrust Belt, Ionian Sea, northwest Greece*, A. Maravelis, G. Makrodimitras, N. Pasadakis, A. Zelilidis (2013)
- *Geochemistry of Upper Miocene-Lower Pliocene source rocks in the Hellenic Fold and Thrust Belt, Zakynthos Island, Ionian Sea, western Greece*, Angelos G. Maravelis, Anna Koukounya, Panagiotis Tserolas, Nikos Pasadakis, Avraam Zelilidis (2015)
- *A comparative organic geochemical study of oils seeps in Western Greece*, Nikos Pasadakis, Vithleem Dagounaki, Elina Chamilaki (2016)

The type of data gathered from all of these studies includes information on Rock-Eval, carbon isotope measurements, gas chromatography results, steranes, hopanes, and terpanes. In addition to these papers, data regarding alkanes and hydrocarbon components were also collected from four diploma theses done by students of Nikos Pasadakis in recent years. They are the following papers (see Works Cited for full citations):

- *Οργανική Γεωχημική Μελέτη Σχηματισμών της Ζακύνθου [Organic Geochemical Study of Formations in Zakynthos]*, Anna Koukounya, under Nikos Pasadakis, Emmanuel Manoutsoglou, Avraam Zelilidis (2014)
- *Οργανική Γεωχημική Μελέτη Βιτουμενιούχων Σχηματισμών της Ηπείρου [Organic Geochemical Study of Bituminous Formations in Epirus]*, Varvara-Aristea Klokotini, under Nikos Pasadakis, Emmanuel Manoutsoglou, Kimon Christanis (2015)
- *Οργανική Γεωχημική Μελέτη Νεογενών Σχηματισμών της Ζακύνθου [Organic Geochemical Study of Neogene Formations in Zakynthos]*, Stilianos G. Papoulas, under Nikos Pasadakis, Emmanuel Manoutsoglou, Vasileios Karakitsios (2016)
- *Γεωχημικός Χαρακτηρισμός Μητρικών Σχηματισμών Πετρελαίου της Κέρκυρας [Geochemical Characterization of Petroleum Formations in Kerkyra (Corfu)]*, Nikos Tsochantaris, under Nikos Pasadakis, Nikolaos Kallithrakas-Kontos, Avraam Zelilidis (2017)

The first type of data gathered from the papers are results of a type of geochemical analysis called Rock-Eval Pyrolysis. This analysis entails taking a kerogen sample and placing it in an environment – in this case, an oven – and subjecting the sample to a specific temperature in an atmosphere of helium. The sample then undergoes the process of volatilization, in which the sample is vaporized. It is then possible to determine the quantity of free hydrocarbons, hydrocarbon and hydrocarbon-like compounds, volatiles containing oxygen, carbon dioxide, and water produced during volatilization (Tissot *et al.*, 1985). The pyrolysis is programmed to do the following: for three minutes, the oven is kept at a temperature of 300 degrees Celsius (or 572 degrees Fahrenheit) and free hydrocarbons are released (“Rock Eval Pyrolysis” n.d.). After this, the temperature is gradually increased to 550 degrees Celsius (or 1,022 degrees Fahrenheit); at this temperature, heavier compounds are released. Carbon dioxide is freed during the process, and is also released (“Rock Eval Pyrolysis” n.d.).

Four parameters are attained during the Rock-Eval pyrolysis. These parameters are designated as S1, S2, S3, and T_{max}. The S1 parameter represents the number of free hydrocarbons; if the value of S1 is greater than 1 mg/g, there may be the presence of an oil show (“Rock Eval

Pyrolysis" n.d.). Unusually high values of S1 could indicate sample contamination by muds and drilling fluids ("Rock Eval Pyrolysis" n.d.). The S2 parameter represents the amount of hydrocarbons that has been generated during the pyrolysis and is an indicator of how much oil and gas the sample can produce if burial and maturation continue ("Rock Eval Pyrolysis" n.d.). The S3 parameter denotes how many milligrams of carbon dioxide is produced per gram of rock during pyrolysis ("Rock Eval Pyrolysis" n.d.). This parameter is used to determine how much oxygen is present in the sample; very high values of S3 indicate that the samples were contaminated, although high concentrations of carbonates in the sample can also yield high values of S3 ("Rock Eval Pyrolysis" n.d.). The T_{max} parameter represents the temperature at which the greatest quantity of hydrocarbons is released during pyrolysis, usually at the height of the S2 peak ("Rock Eval Pyrolysis" n.d.). and indicates the maturation stage. Other parameters used in the analysis of Rock-Eval pyrolysis can be calculated from the four parameters obtained during the pyrolysis – these include the hydrogen index HI, the oxygen index OI, the production index PI, and pyrolyzable carbon PC (see Equations 1 through 4 below).

$$HI = \frac{100*S2}{TOC} \qquad \text{Eq. 1}$$

$$OI = \frac{100*S3}{TOC} \qquad \text{Eq. 2}$$

$$PI = \frac{S2}{S1+S2} \qquad \text{Eq. 3}$$

$$PC = 0.083 * (S1 + S2) \qquad \text{Eq. 4}$$

in which TOC stands for the Total Organic Carbon, which is related to the amount of kerogen in the sample (Gluyas and Swarbrick, 2004).

The HI characterizes the origin of the organic matter and values range from approximately 100 to 600. It is possible to determine if the organic matter originated in marine environments or terrestrial environments due to the fact that marine organic matter contains lipids and proteins compared to the carbohydrates that comprise terrestrial organic matter. This means that the ratio of hydrogen to carbon is higher in marine organic matter than terrestrial organic matter ("Rock Eval Pyrolysis" n.d.). The OI represents the ratio of oxygen to carbon, which is usually high for organic matter that is terrestrial in origin, and has a value between 0 to approximately 150 ("Rock

Eval Pyrolysis” n.d.). The PI is a parameter that is used to determine the degree of thermal maturation of the organic matter (El Nady and Hammad, 2015). The PC represents the amount of carbon within the hydrocarbons that have undergone the volatilization and pyrolyzation of the analysis (“Rock Eval Pyrolysis” n.d.).

Carbon isotope measurements are another type of data collected in this research – they are performed in geochemical studies to determine information about the sample, such as maturity and genetic correlation (Stahl 1979). The carbon isotope content of a sample depends upon the composition of the original organic matter, and on the isotope fractionation that occurs during the process or alteration of the organic matter over time (Tissot *et al*., 1985). Such measurements are conducted using the following equation (Equation 5) (Stahl 1979):

$$\delta = \frac{\left({}^{13}C/{}^{12}C\right)^{sample} - \left({}^{13}C/{}^{12}C\right)^{standard}}{\left({}^{13}C/{}^{12}C\right)^{standard}} \cdot 1000\,(\%\,o) \qquad \text{Eq. 5}$$

In which ^{13}C is the carbon isotope with seven neutrons and ^{12}C is the carbon isotope with six neutrons. The most commonly used standard value of $^{13}C/^{12}C$ is Peedee Belemnite (PDB) (Tissot *et al*., 1985). This measurement makes it possible to determine the difference between marine and terrestrial photosynthesis of the original organic matter; marine plants use carbonate complexes in seawater, while terrestrial plants use atmospheric carbon dioxide that contains a lower value of ^{13}C (Tissot *et al*., 1985). In addition, it can be noted that biogenic methane generated by microorganisms has higher quantities of the ^{12}C isotope, while carbon dioxide generated by microorganisms has higher quantities of the ^{12}C isotope (Tissot *et al*., 1985).

Another type of data gathered in the database are the results of gas chromatography. This technique is used to determine the composition of the gas or liquid sample (Dandekar 2013). This technique is particularly useful, since it is possible to perform analyses by type and classify the oil fractions. (Beens and Brinkman, 2000). Gas chromatography is carried out by vaporizing a sample in an oven at a certain temperature and transporting it with a gas into a column that separates the components of the sample – the lighter components are eluted first, followed by the heavier components (Dandekar 2013). Some of the data gathered in the database also includes information on kerogen composition and maturity measurements. This data reflects the type of material within the kerogen, such as amorphous versus algal material, and the quantity of macerals (original organic material) (Gluyas and Swarbrick, 2004).

Data Description

The study done by Seifert *et al*., 1984 was one of the first papers published on crude oils in western Greece. The samples analyzed in the study were from several regions in western Greece – Epirus, in northwestern continental Greece; Trifou and Killini, in southwestern continental Greece in the western Peloponnese; Zakynthos Island, Marathopolis, and Katakolon, in the western Peloponnese. One sample from the Prinos field in the Aegean Sea was added to the study due to its standing as the only commercially produced oil in Greece at the time (Seifert *et al*., 1984). The study summarized its biochemical analysis on steranes, terpanes, and hopanes, and the data provided in the paper was added to the database.

The next study, done in 1986 by Palacas *et al*., was a joint research project done by the U.S. Geological Survey and the Public Petroleum Corporation of Greece (DEP) that focused on the geochemistry of hydrocarbon samples based on the study done by Seifert *et al*. in 1984. The data came from several localities in Epirus, Katakolon, Zakynthos Island, Paxi Island, and Sterea (Palacas *et al*., 1986). As with the study done by Seifert *et al*., 1984, this study focused on the biochemical analysis of the samples, including information such as carbon isotope concentrations, terpanes, and steroids, which were also added to the database.

The third study used in this project was done by Rigakis *et al*., 1998 on source rocks in the Ionian zone. This study investigated the geological history of the Ionian basin and the potential source rocks in the area, as well as their hydrocarbon potential. This paper includes data on kerogen composition and significant biomarker ratios of samples taken from a variety of locations in western Greece: Gotzikas, Elataria, Mavronoros, Ioannina, Dragopsa, and northern Mavroudi (Rigakis *et al*., 1998). A depositional model was created to illustrate the source rock geometry in the Ionian zone and the likely geometry of the hydrocarbons in the source rock according to age and depth (Rigakis *et al*., 1998). The bulk of the raw data consisted of results from Rock-Eval pyrolysis, which was crucial information added to the database.

The next study was conducted by Rigakis *et al*., 2007 analyzing a selection of oil shows from western Greece including those from drilled wells. This research focused on samples from several localities in the Epirus region, the Aitoloakarnania region, and northwestern Peloponnese (Rigakis *et al*., 2007). This study notes that samples from Zakynthos and Paxi Islands were particularly significant, and presented results regarding carbon isotopes and biomarkers (Rigakis *et al*., 2007). The raw data included in the paper were carbon isotope measurements and biomarker ratios such as those of steranes and terpanes (Rigakis *et al*., 2007).

The fifth study from which data was collected was a preliminary research project done by Rallakis *et al*., 2013 on the maturity of samples of organic matter from the Ionian zone. This study worked on samples from several sites – Elataria, Giromeri, Dragopsa, Kokkinolithari, Yurganista, and Sayada, in the Epirus region of western Greece (Rallakis *et al*., 2013). The results focused on determining certain initial organic matter parameters, such as the total organic carbon (TOC) content, vitrinite reflectance, and mineralogical composition of the samples (Rallakis *et al*., 2013). The data presented in the study regarding the organic matter was included in the database.

The next study included in the database was carried out by Maravelis *et al*., 2013 on the geological history, stratigraphic evolution, and source rock potential of structures in the Ionian zone. The samples used in this study originate from three small islands close to Corfu – Othonoi, Mathraki, and Ereikoussa Islands. Several different formations and facies associations were identified in the field study, and 53 samples were collected (Maravelis *et al*., 2013). Of these samples, sixteen samples were determined to be of interest and were used for Rock-Eval pyrolysis (Maravelis *et al*., 2013). The data from this analysis was also included in the database.

The seventh study was a research project done by Maravelis *et al*., 2015 regarding the geochemistry of samples taken from Zakynthos Island. This location has a unique geology with outcrops that allow for easy access and analysis. Twenty-seven samples were collected and analyzed with techniques including Rock-Eval pyrolysis, bitumen extraction, and gas chromatography-mass spectrometry (Maravelis *et al*., 2015). The raw data presented in the paper – Rock-Eval pyrolysis and gas chromatography-mass spectrometry data – were added to the database.

The eighth and final study included in this research was conducted by Pasadakis *et al*., 2016 as a comparison study of geochemical analysis methods. The samples utilized in this research are from three separate oil shows in western Greece: Dragopsa, Lavdani, and Zakynthos Island (Pasadakis *et al*., 2016). Analysis was performed to determine the maltene composition and biomarker indices, such as steranes and terpanes (Pasadakis *et al*., 2016). The raw data provided by this study includes maltene fraction results of the three geochemical analysis methods, as well as indices of terpanes and hopanes; all of this information was included in the database.

The four diploma theses papers mentioned previously were invaluable sources of alkane data that were added to the database. The thesis written by Anna Koukounya focused on samples taken from Zakynthos Island; her research was a part of the paper done by Maravelis *et al*., 2015. Another thesis, written by Stilianos Papoulas, was also done on samples from Zakynthos Island. The next thesis, written by Varvara-Aristea Klokotini, concentrated on samples taken from Epirus. The most recent diploma thesis was done in 2017 by Nikos Tsochantaris on samples taken from Corfu. These papers are significant, as they include the most information about alkanes, which will allow for more comparative analyses with the samples from western Greece.

The Database

The database itself, titled "Western Greece Database", is meant to be a collective file that can be added to as research on hydrocarbon samples in western Greece continues. All of the data mentioned previously is arranged in Microsoft Excel spreadsheets according to data type. The first two spreadsheets include the Rock-Eval pyrolysis results; the first spreadsheet organizes the data by the type of formation from which the sample originates, while the second spreadsheet organizes the data by the age of the formation. These two spreadsheets contain data from nine papers, including Rock-Eval data from the diploma theses. The next two spreadsheets are dedicated to the alkanes from the four diploma theses, and are arranged by paper and age in the third and fourth spreadsheets, respectively. The fifth spreadsheet includes data on the percentage of saturates and aromatics of samples collected from three papers. The sixth spreadsheet contains data regarding carbon isotope measurements from three papers. The seventh spreadsheet in the Excel file is for gas chromatography data from Maravelis *et al*., 2015. The eighth and ninth spreadsheets contain biomarker information; the eighth spreadsheet includes data on steranes from five studies, while the ninth spreadsheet includes data on terpanes and hopanes from four studies. The tenth spreadsheet is dedicated to kerogen information from Rigakis *et al.*, 1998 that includes data regarding maturity indicators, the thermal alteration index, and percentage of kerogen concentrates. The eleventh and final spreadsheet covers data that do not fit in with any of the previous spreadsheets. The papers used for this research have been given numerical designations for the purpose of identification in the Excel file; there is a Microsoft Word document that describes the corresponding papers, titled "Designation of References used in the Western Greece database".

Processing Data with MATLAB

Once all of the data was collected and organized in the Western Greece database, it was possible to analyze the information with the use of the MATLAB coding program. Some of the data in the database is incomplete; thus, analysis was done only for the Rock-Eval data and the alkanes. Future analysis may be conducted as more additions are made to the database. The MATLAB code used for data analysis can be seen in the Appendix.

Rock-Eval Pyrolysis Data

MATLAB was used to create seven different charts from the data of more than three hundred samples that were analyzed using Rock-Eval pyrolysis. These charts include the following: HI vs T_{max}, HI vs TOC, PI vs T_{max}, S1 and S2 vs TOC, S1 vs TOC, S2 vs TOC, and a van Krevelen diagram, to determine the type of kerogen of the samples, as well as other information. Since some of the data was incomplete, the results for those samples were not used in creating the charts. As the data was organized by formation and age, two sets of charts were created to illustrate the kerogen relations among the samples.

There are four types of kerogens; liptinite, exinite, vitrinite, and inertinite (Gluyas and Swarbrick, 2004). Each of these types of kerogen develops according to the original organic material and the depositional environment (Gluyas and Swarbrick, 2004). In addition, each type of kerogen can yield a different type of petroleum (Gluyas and Swarbrick, 2004). Liptinite, also known as Type I, is a fairly rare kerogen named for its high concentrations of lipids and easily yields oil (Gluyas and Swarbrick, 2004). It has a high ratio of hydrogen to carbon and a low ratio of oxygen to carbon (Gluyas and Swarbrick, 2004). Type I kerogen originates from algae that formed in environments such as lakes and lagoons (Gluyas and Swarbrick, 2004). Exinite, known as Type II, is the most common type of kerogen and contains more moderate amounts of hydrogen, oxygen, and carbon (Gluyas and Swarbrick, 2004). It produces both oil and gas, although in lesser quantities than Type I kerogen. Type II kerogen originates from plant debris such as spores and pollen, as well as marine phytoplankton and bacterial microorganisms (Gluyas and Swarbrick, 2004). The development of Type II kerogen can be heavily influenced by sulfur – exinite containing high amounts of sulfur are known as Type II-S kerogens (Gluyas and Swarbrick, 2004). Vitrinite, known as Type III, is a low-yield kerogen that typically produces gas and has low ratios of hydrogen to carbon and high ratios of oxygen to carbon (Gluyas and Swarbrick, 2004). Type III kerogens tend to originate from plant debris that forms coal. Inertinite, also known as Type IV, has little to no potential of producing oil and gas, with high quantities of carbon but low quantities of hydrogen (Gluyas and Swarbrick, 2004). These kerogens can also be identified by fluorescence under ultra-violet light; vitrinite in particular is significant since it fluoresces with greater maturity and can be used as an indicator of source rock development, while inertinite does not fluoresce at all (Gluyas and Swarbrick, 2004).

Alkanes Data

MATLAB was also used to work with the alkanes data from the diploma theses. There are sixty-eight samples in this data set, which are arranged by diploma thesis and by age, in order to illustrate the differences between the groups. The alkanes data covers the components from C_{14} through C_{35} as well as other alkane parameters. Statistical analysis was implemented and bar charts, box plots, and a dendrogram were created to understand the composition of the various samples used in the diploma theses. The bar charts are divided into two groups according to the diploma thesis from which the data was taken, and the age of the samples. The box plots created are meant to be used as a reference and can be seen in the Appendix. The dendrogram was created using all of the data from the diploma theses without separating the data into categories according to age or formation. This data was normalized and hierarchical clustering methods were applied to create the dendrogram.

Hierarchical clustering is a method that analyzes the distances between data points and creates a dendrogram to illustrate the relationship – if one exists – among the data and classify patterns into groups (Jain *et al*., 1999). There are two types of algorithms used for calculation in hierarchical clustering. The first type is the agglomerative algorithm, in which each piece of data is treated as a single cluster that is taken and merged with the next closest cluster to create a new cluster (Rencher 2002). These steps are reiterated until the entire data set is included in the cluster, but the process is irreversible (Rencher 2002). The second type of algorithm is the divisive algorithm, in which there is one cluster containing all of the data (Rencher 2002). At each iteration, the cluster divides into another cluster until each has a single piece of data (Rencher 2002). However, once the process is finished, each piece of data cannot be moved to other clusters (Rencher 2002). In order to determine which algorithm is utilized, it is necessary to measure the similarity or dissimilarity of the data. This can be done by using linkage functions, which affect how the data is merged or divided into the final cluster.

To create the dendrogram for the alkanes data, it was necessary to use one type of linkage function, called average linkage. This equation takes the average of the distances between all pairs of cluster members in clusters A and B as defined in Equation 6 below.

$$D(A,B) = \frac{1}{n_A n_B} \sum_{i=1}^{n_A} \sum_{j=1}^{n_B} d(y_i, y_j) \qquad \text{Eq. 6}$$

In which the distance is determined between points n_A and n_B (Rencher 2002). The distance used in average linkage is the Euclidean distance, which is the true straight-line distance between two points in Euclidean space ("Euclidean Distance" 2017). The formula for this distance can be seen in Equation 7 below, in which *a* and *b* are the data points in the cluster:

$$\|a - b\|_2 = \sqrt{\sum_{i=1}^{n} (a_i - b_i)^2} \qquad \text{Eq. 7}$$

The results of these methods performed on the alkanes data can be seen in the following section (see Figure 37).

Results

The following section describes the results of the Rock-Eval pyrolysis and the alkanes data. The Rock-Eval pyrolysis results review each chart according to the formation and the age of the samples. The results for the alkanes data describe a brief overview of the boxplots that were generated and are available in the Appendix, followed by reviewing the alkanes data first according to diploma thesis, then according to the age of the samples. The last part of this section is a description of the dendrogram for the alkanes data.

Rock-Eval Pyrolysis Results

The data analysis for the Rock-Eval pyrolysis results in the database were arranged by formation and by age. It must be noted that the data used to plot the charts vary slightly, as some entries for the samples in the database do not include the full information regarding the maximum temperature (T_{max}) and the total organic carbon (TOC). The first result, seen in Figures 12 and 13 below, show the results for the hydrogen index versus the maximum temperature.

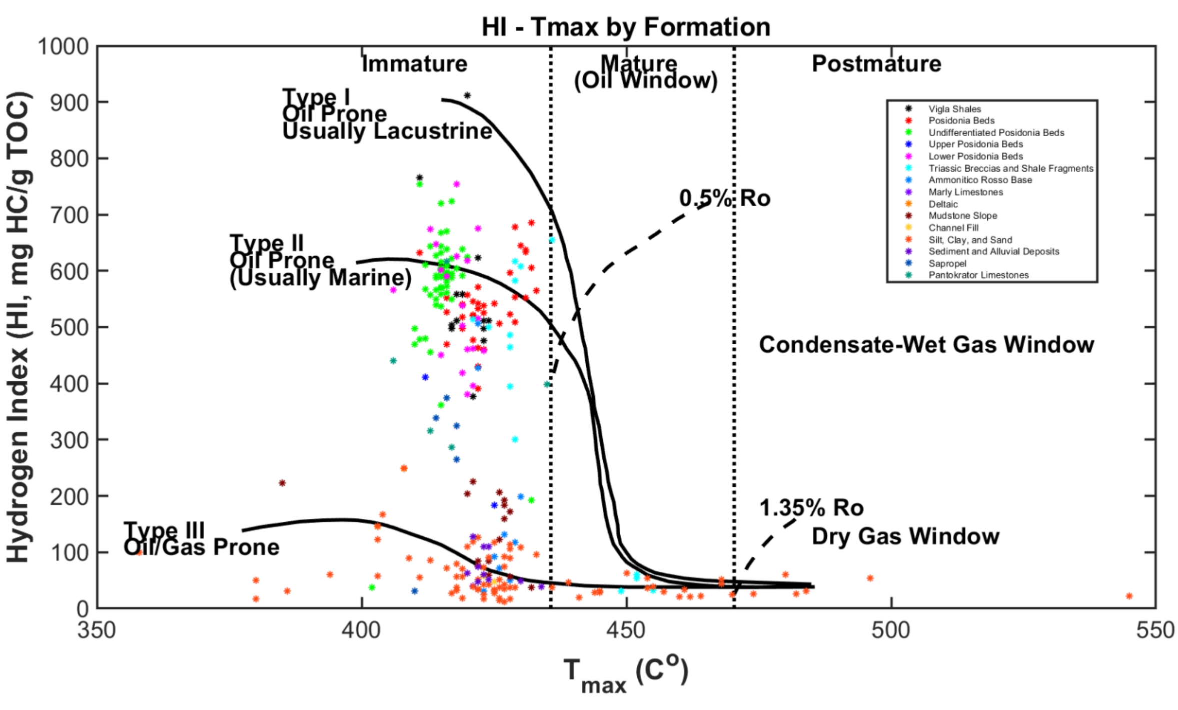

Figure 12 – Rock-Eval Pyrolysis Results for HI-Tmax According to Formation

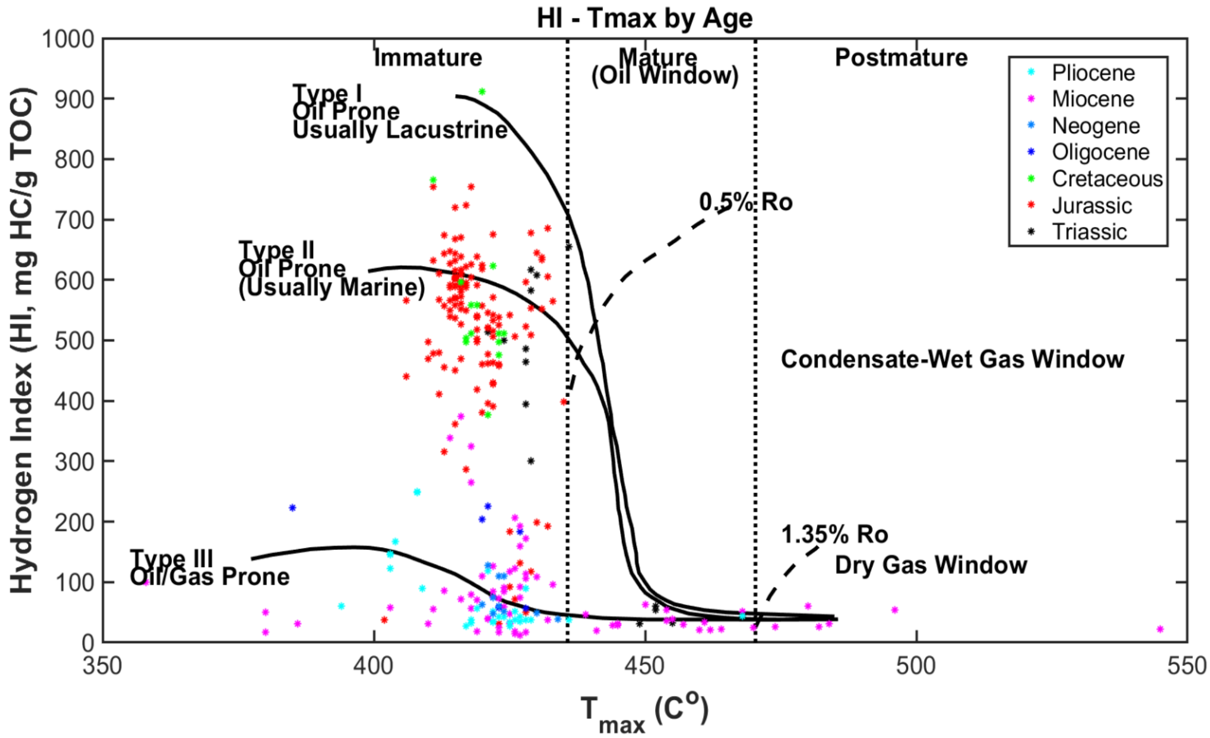

Figure 13 – Rock-Eval Pyrolysis Results for HI-Tmax According to Age

In Figure 12, plotting the hydrogen index (HI) versus the maximum temperature (T_{max}) yields ratios that illustrate the type of hydrocarbons present, as well as their likely origin. According to Figure 12, the majority of the samples are immature, originate from marine environments, and can be classified as mostly Type II and Type III kerogens. In addition, it appears that the following formations: Deltaic; Mudstone Slope; Channel Fill; Silt, Clay, and Sand; Sediment and Alluvial Deposits; and Sapropel – are all Type III kerogens that are more likely to produce both oil and gas. The samples from the Silt, Clay, and Sand formation have a wide range of maturity from immature to postmature, indicating a possibility for the presence of dry gas; some of the Triassic Breccias and Shale Fragments samples are also classified as mature. The rest of the formations, including the Pantokrator Limestones are clustered mainly around the Type II kerogen category; however, the samples from the Triassic Breccias and Shale Fragments range from immature Type II to mature Type III kerogens. The results also show that although there are a few samples from the Vigla Shales that can be labeled as immature Type I kerogens, the majority of the samples are clustered around the immature Type II kerogens group.

Figure 13 above shows the same results as in Figure 12; however, they have been classified according to the age of the samples. According to Figure 13, it appears that the samples that cluster around the Type II kerogen group are the Triassic, Jurassic, and Cretaceous age samples. The samples that are grouped around the Type III kerogens are the Oligocene, Neogene, Miocene, and Pliocene age samples, including a few samples from the Jurassic. These results are encouraging in that it appears that the older samples are more likely to produce oil from marine environments, while the younger samples are more likely to produce both oil and gas. Several of the Triassic samples appear to be mature, and there are several samples of Miocene age and one sample from Pliocene age that are also located in the mature category. Several Miocene samples are also in the postmature category.

By examining both Figures 12 and 13, it is possible to see that the more recent Neogene, Miocene, and Pliocene age samples of the Deltaic; Mudstone Slope; Channel Fill; Silt, Clay, and Sand; Sediment and Alluvial Deposits; and Sapropel formations are all Type III kerogens. In addition, the older Triassic, Jurassic, and Cretaceous age samples of the remaining formations (Vigla Shales; Posidonia Beds; Undifferentiated Posidonia Beds; Upper Posidonia Beds; Lower Posidonia Beds; Triassic Breccias and Shale Fragments; Ammonitico Rosso Base; Marly Limestones; Pantokrator Limestones) are grouped around the Type II kerogen category.

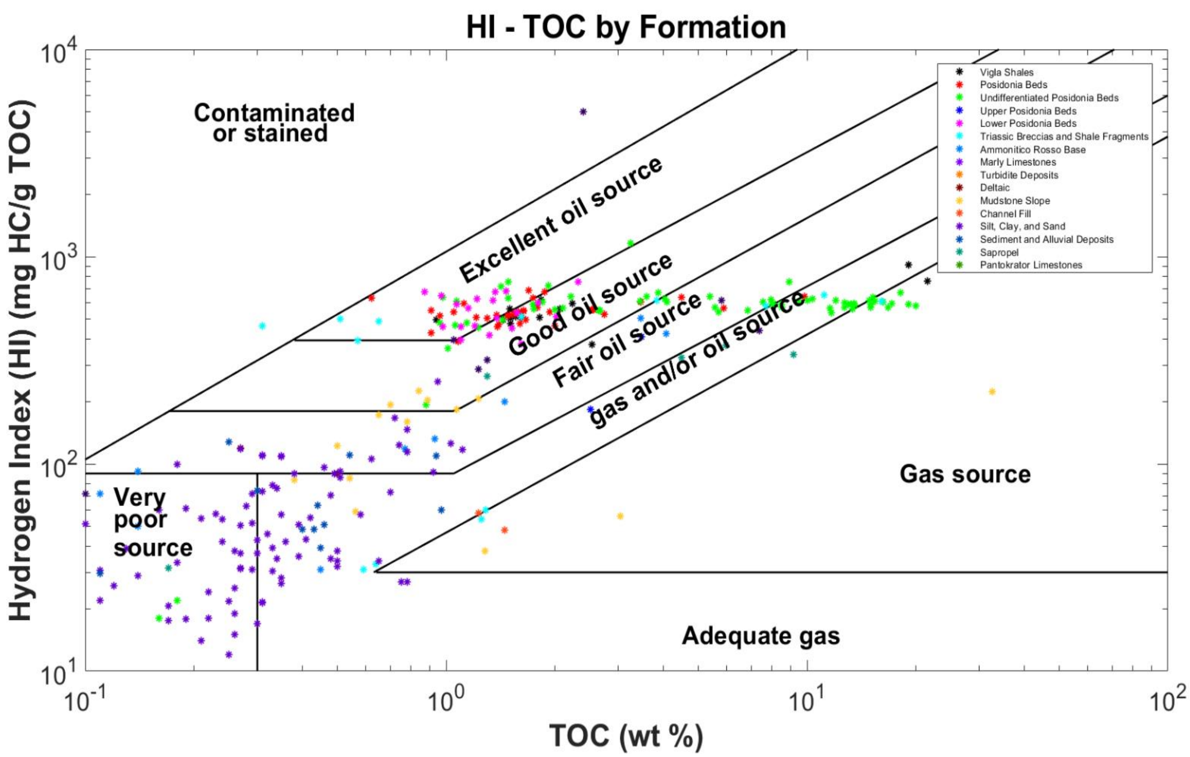

Figure 14 – Rock-Eval Pyrolysis Results for HI-TOC According to Formation

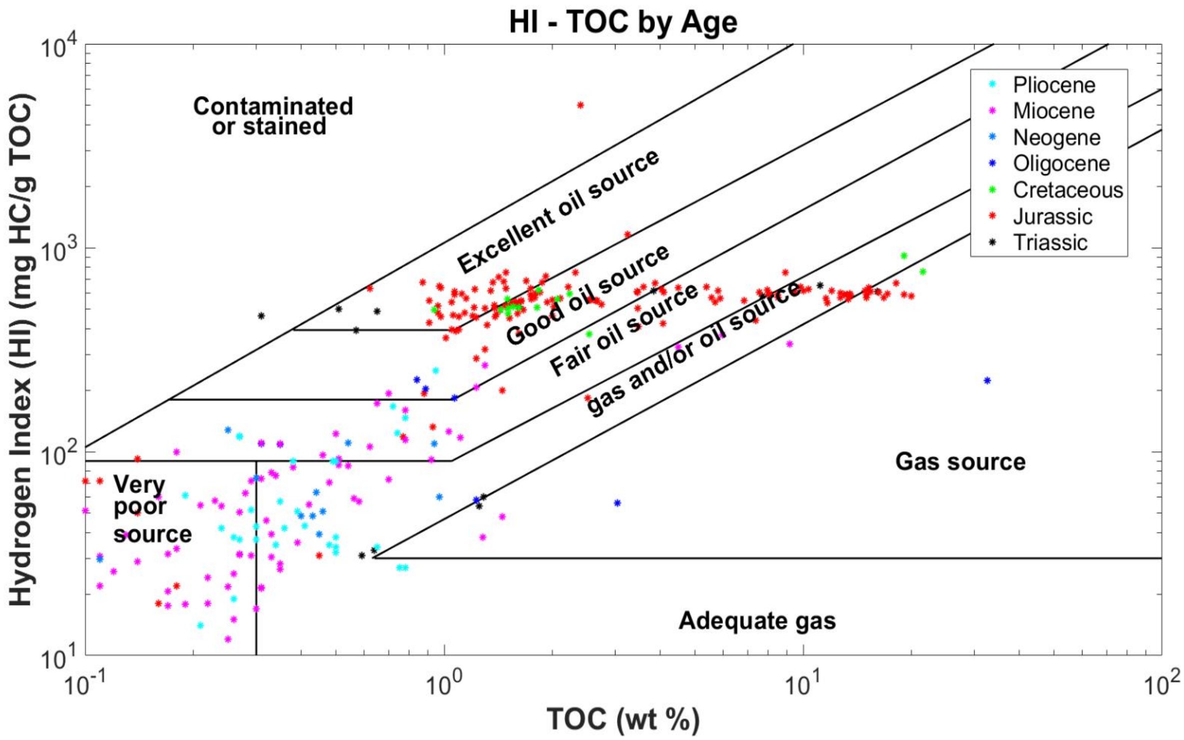

Figure 15 - Rock-Eval Pyrolysis Results for HI-TOC According to Age

Figures 14 and 15 show the results of plotting the hydrogen index (HI) versus the total organic carbon (TOC) according to both formation type and age of the sample, respectively. Both plots show whether or not the samples are dependable oil or gas sources, and if they are contaminated. According to Figure 14, most of the samples are classified as oil sources, with a few individual samples from the Pantokrator Limestones, Undifferentiated Posidonia Beds, Vigla Shales, Triassic Breccias and Shale Fragments, Channel Fill, and Mudstone Slope formations that appear to be categorized as gas sources. Two samples – one each from the Vigla Shales and the Triassic Breccia and Shale Fragments – are classified as contaminated or stained. The results show that some of the formations are very poor sources of hydrocarbons – such as samples from the Marly Limestones, Sediment and Alluvial Deposits formations – as well as some of the samples from the Undifferentiated Posidonia Beds, Pantokrator Limestones, Ammonitico Rosso Base, Mudstone Slope, and Triassic Breccias and Shale Fragments formations. The formations that are clustered in the excellent oil source group are the Vigla Shales, Posidonia Beds, Undifferentiated Posidonia Beds, Lower Posidonia Beds, and Triassic Breccias and Shale Fragments. The formations that are grouped in the good oil source category include the Vigla Shales, Posidonia Beds, Undifferentiated Posidonia Beds, Lower Posidonia Beds, Triassic Breccias and Shale

Fragments, and Mudstone Slope, as well as a sample each from the Sapropel and the Silt, Clay, and Sand formations. The fair oil source category contains the following formations: the Vigla Shales, Posidonia Beds, Undifferentiated Posidonia Beds, Triassic Breccias and Shale Fragments, Ammonitico Rosso Base, Upper Posidonia Beds, Mudstone Slope, and Silt, Clay, and Sand. The formations that appear to be categorized as a gas and/or oil source are the Undifferentiated Posidonia Beds, the Triassic Breccias and Shale Fragments, and a few samples of the Vigla Shales, Posidonia Beds, Upper Posidonia Beds, and Sapropel formations.

Figure 15 shows the results of plotting the HI versus the TOC by age of the samples. According to the chart, the very poor oil source category consists mainly of Pliocene, Miocene, and Neogene age samples, with some samples that date back to the Triassic and Jurassic periods. In addition, some of the Pliocene and Miocene samples appear to be somewhat of a fair oil source. The majority of the remaining samples, especially those of Triassic, Jurassic, and Cretaceous in age, appear to be spread out among the excellent, good, and fair oil source categories. The samples from the Oligocene are mostly categorized as a good oil source. The two samples that are contaminated or stained are from the Triassic and the Jurassic periods. The samples that are categorized as a gas source include samples that date back to the Triassic, Jurassic, Cretaceous, Oligocene, and Miocene.

By comparing both Figures 14 and 15, it is apparent that the very poor oil source samples are from the newer formations (the Silt, Clay, and Sand formation and the Sediment and Alluvial Deposits formation) of Pliocene and Miocene age. According to both figures, it appears that the more dependable oil sources are the older formations (the Vigla Shales, Posidonia Beds, Undifferentiated Posidonia Beds) of the Triassic, Jurassic, and Cretaceous periods.

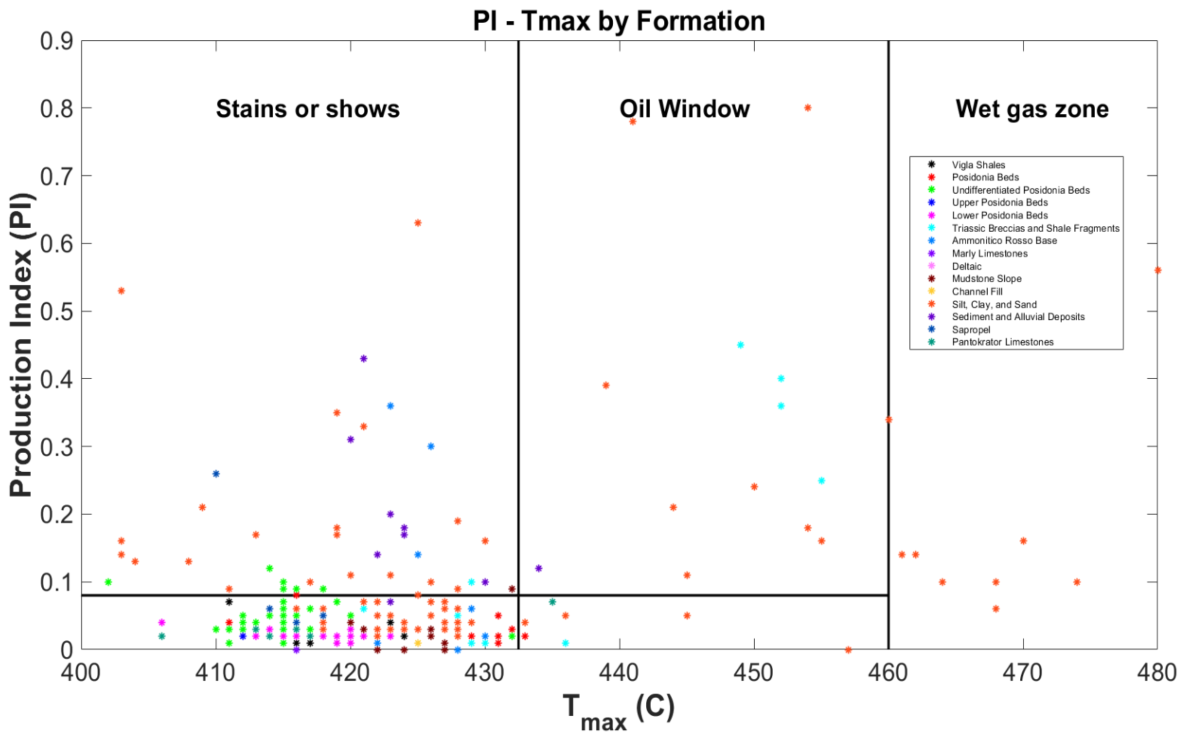

Figure 16 – Rock-Eval Pyrolysis Results for PI-Tmax According to Formation

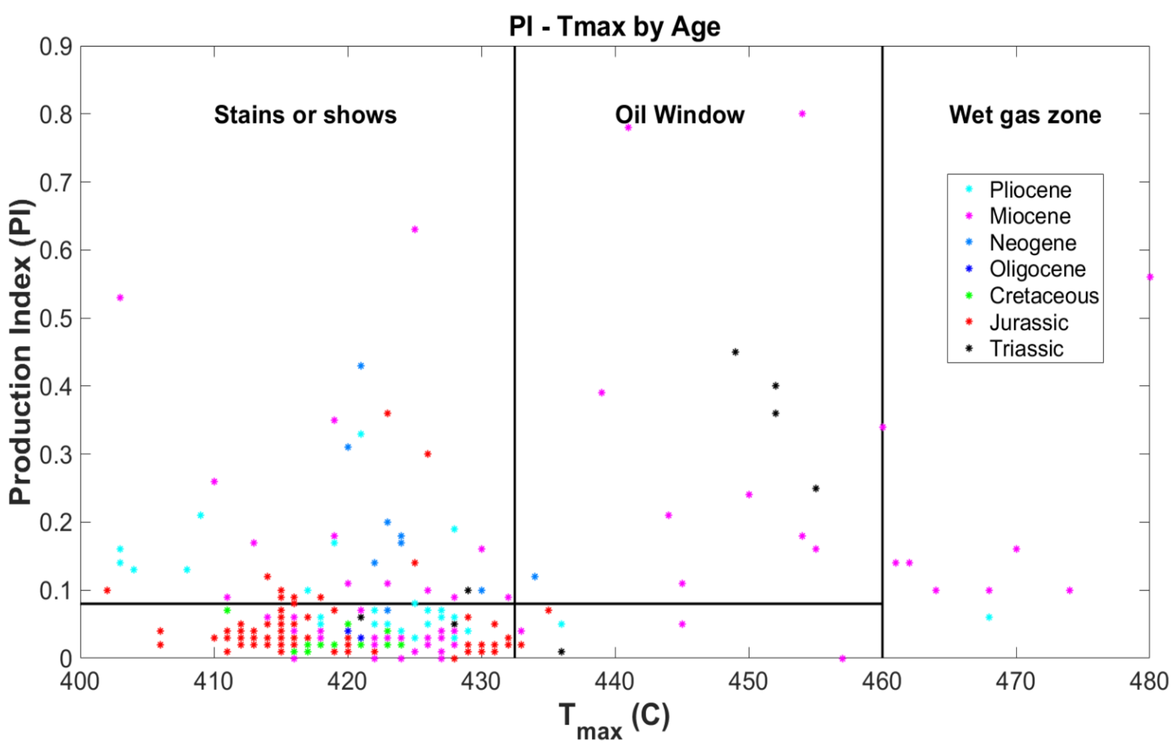

Figure 17 – Rock-Eval Pyrolysis Results for PI-Tmax According to Age

The next set of charts represents the production index (PI) versus the maximum temperature (Tmax), which indicate whether the sample can be classified as being an oil stain or show, within the oil window, or within the wet gas zone. Figure 16 shows that the majority of the formations are classified as oil stains or shows. However, there are some samples from the Undifferentiated Posidonia Beds and the Silt, Clay, and Sand formations – as well as a sample each from the Sediment and Alluvial Deposits formation and the Pantokrator Limestones – that are located in the oil window category. The samples that are classified as being in the wet gas zone all belong to the Silt, Clay, and Sand formation.

Figure 17 shows the results of the PI versus the Tmax, plotted according to the age of the samples. The samples that are classified as being in the oil window are some of the Triassic and Miocene samples, as well as a few samples from the Jurassic, Neogene, and Pliocene age. The samples that are in the wet gas zone are mostly from the Miocene, with one sample from the Pliocene. However, it must be noted that all of the samples in the oil window and wet gas zone of the aforementioned ages are also classified as oil stains or shows. Both Figure 16 and Figure 17 indicate that the majority of the samples are oil stains and oil shows. The data points located in the oil window and wet gas zone correspond to Triassic Breccias and Shale Fragments, as well as the more recent Miocene-age Silt, Clay, and Sand formation.

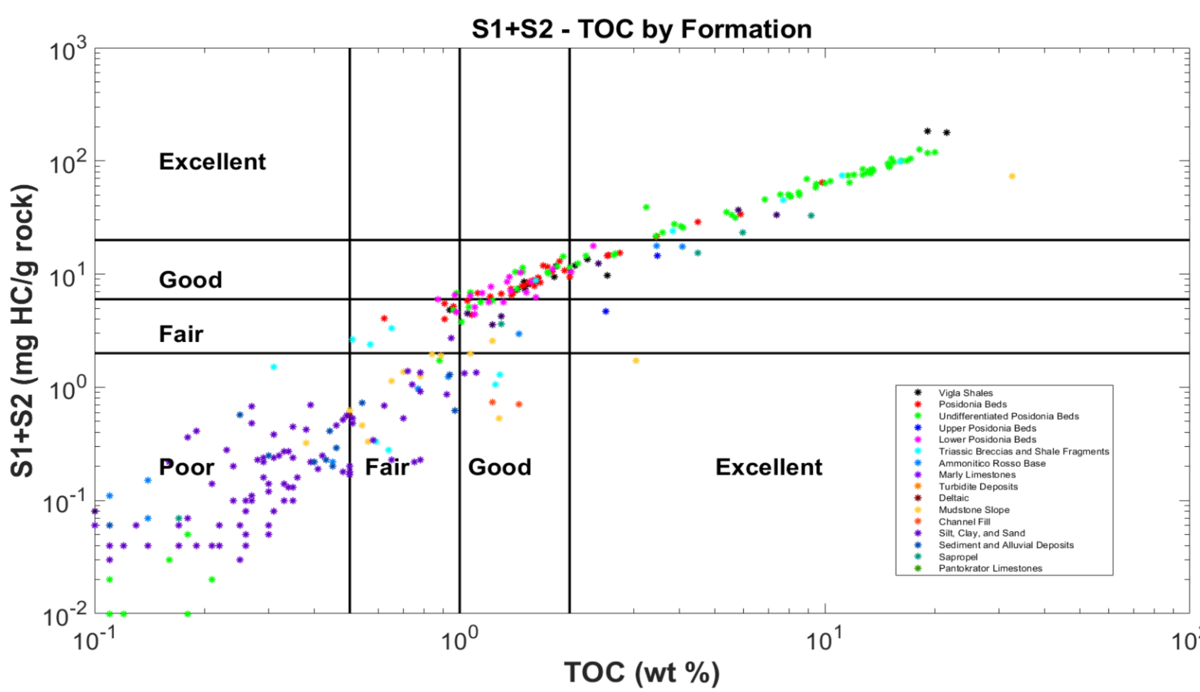

Figure 18 – Rock-Eval Pyrolysis Results for S1+S2-TOC According to Formation

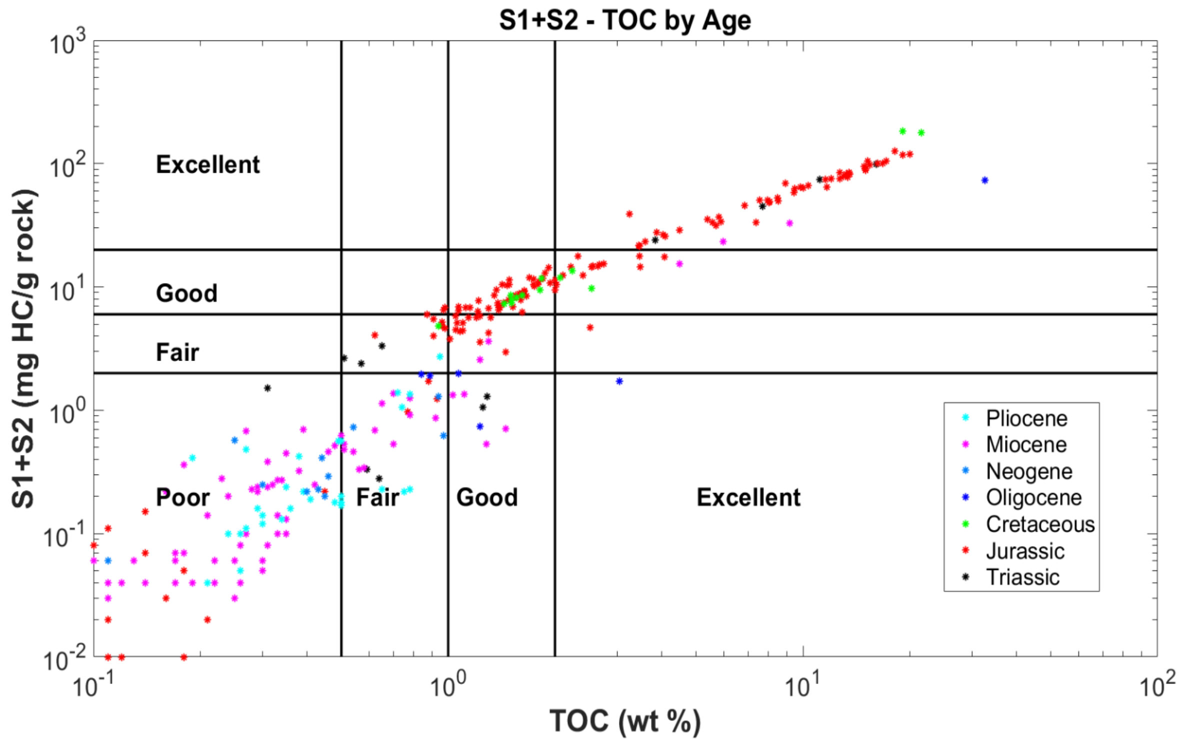

Figure 19 – Rock-Eval Pyrolysis Results for S1+S2-TOC According to Age

The next two images outline the results for graphing S1+S2 versus the TOC. These charts indicate the potential of the sample to generate hydrocarbons. Figure 18 shows the results arranged by formation for poor, fair, good, and excellent potential of the samples for hydrocarbon generation. The formations that have been categorized with a poor potential are the Silt, Clay, and Sand formation as well as the Sediment and Alluvial Deposits. Other samples in this category include a few from Undifferentiated Posidonia Beds, Pantokrator Limestones, Ammonitico Rosso Base, and Mudstone Slope, including one sample from the Triassic Breccias and Shale Fragments formation. The formations that are classified with fair to good potential include some of the Silt, Clay, and Sand samples, as well as Vigla Shales, Posidonia Beds, Undifferentiated Posidonia Beds, Upper Posidonia Beds, Lower Posidonia Beds, Triassic Breccias and Shale Fragments, Mudstone Slope, Channel Fill, and Sediment and Alluvial Deposits formations. The samples that appear to have excellent hydrocarbon potential are mostly from the Undifferentiated Posidonia Beds formation. There are a few samples from other formations in this category as well, including the Mudstone Slope, Vigla Shales, Posidonia Beds, Triassic Breccias and Shale Fragments, and Sapropel formations.

Figure 19 shows the same results as in Figure 18, but the data has been arranged by age. The samples that are classified as having poor hydrocarbon generation potential are mainly from the Miocene and Pliocene, with some samples from the Jurassic and Neogene. There is also one sample from the Triassic period that appears to have poor potential for hydrocarbon generation. The samples that have fair to good potential span across all of the ages listed in the legend in Figure 19, including the Jurassic, Cretaceous, and Oligocene aged samples. The samples that have excellent potential for hydrocarbon generation chiefly consist of samples that are Jurassic in age, but there are also a few data points from the Triassic, Cretaceous, Oligocene, and Miocene.

After comparing Figure 18 and Figure 19, it is possible to see that the samples from newer formations that date back to the Miocene and Pliocene (the Sediment and Alluvial Deposits; Silt, Clay, and Sand formations) have poorer potential for hydrocarbon generation. The samples that have the best potential are mainly from the Jurassic period; namely, the Undifferentiated Posidonia Beds. According to Figure 18 and Figure 19, the samples that have a fair to good potential originate from all of the formations and ages.

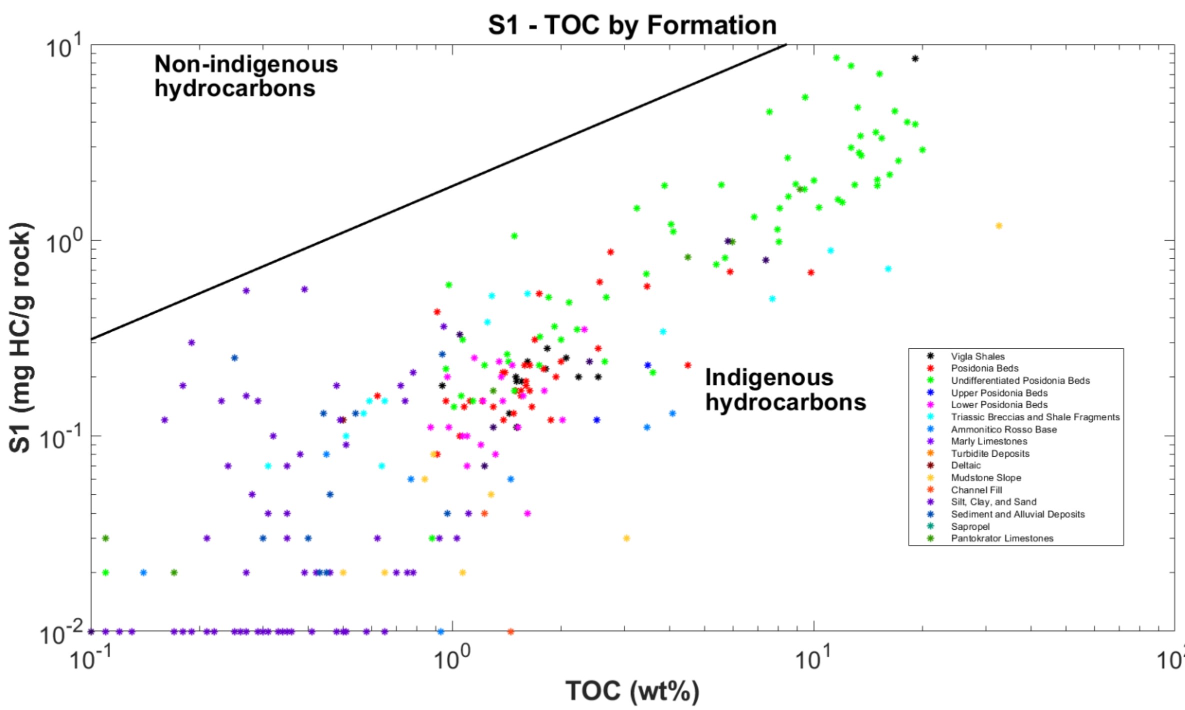

Figure 20 – Rock-Eval Pyrolysis Results for S1-TOC According to Formation

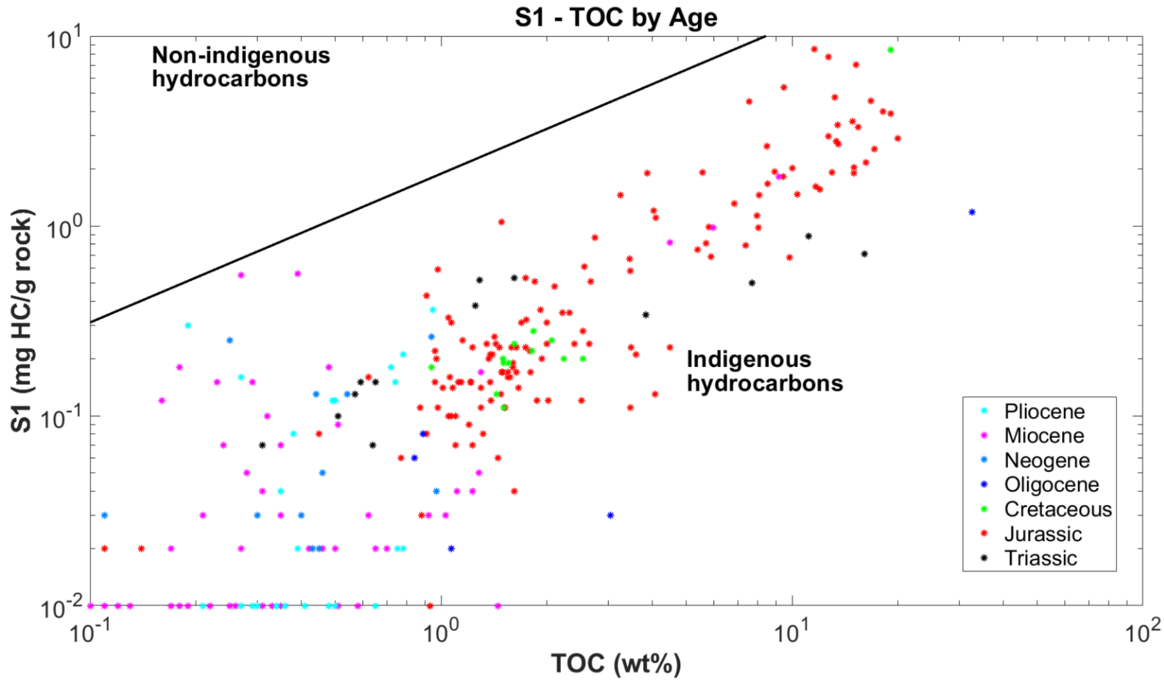

Figure 21 – Rock-Eval Pyrolysis Results for S1-TOC According to Age

The next two plots show the S1 parameter versus the TOC, which indicates whether or not the samples are non-indigenous or indigenous hydrocarbons. In other words, these plots determine if the hydrocarbons have migrated or have been contaminated (non-indigenous), or if they are from their original location of generation (indigenous). Figure 20 shows the results according to the type of formation, while Figure 21 shows the results according to the age of the samples. Both of these figures show the same results – that the samples are indigenous in origin, and appear to have not migrated and have not been contaminated. The data points that are closest to crossing the line dividing the categories in the charts are the samples from the Silt, Clay, and Sand formation that dates back to the Miocene.

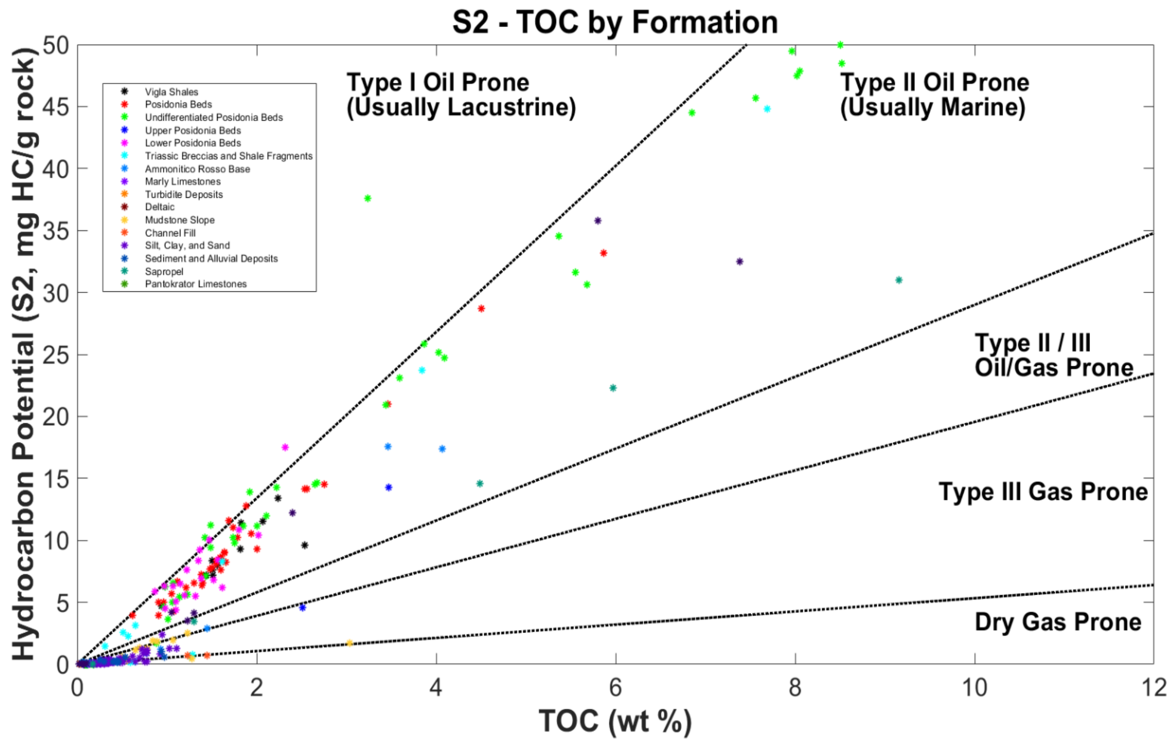

Figure 22 – Rock-Eval Pyrolysis Results for S2-TOC According to Formation

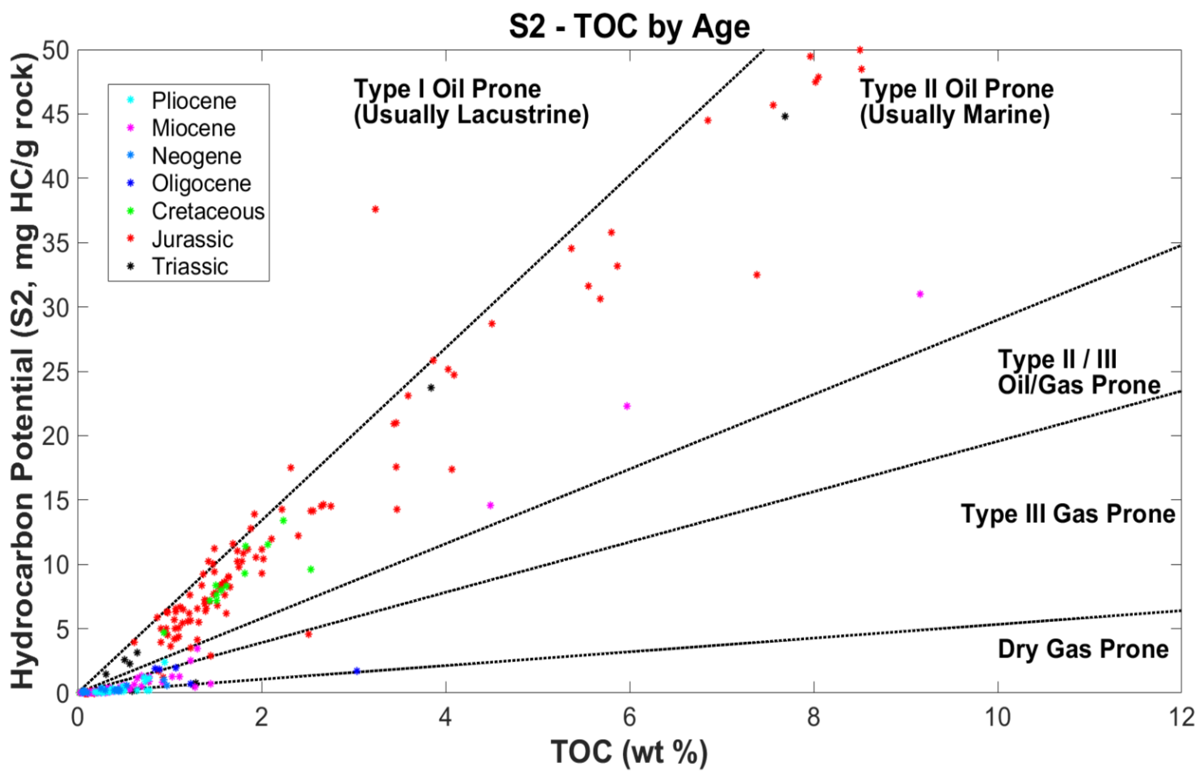

Figure 23 – Rock-Eval Pyrolysis Results for S2-TOC According to Age

The next set of charts shows the S2 parameter versus the TOC; this indicates the type of kerogen and the hydrocarbon potential of the sample. Figure 22 shows the results according to the type of formation. The majority of the samples appear to be Type II kerogens that are oil prone and from a marine environment. Several samples are located along the boundaries for the other types of kerogen. For example, samples from the Mudstone Slope, Ammonitico Rosso Base, Pantokrator Limestones, and Silt, Clay, and Sand formations are Type II/Type III kerogens that are oil and gas prone. However, these samples also have low hydrocarbon potential. There are samples from the Upper Posidonia Beds, Undifferentiated Posidonia Beds, Mudstone Slope, and Silt, Clay, and Sand formations that are categorized as gas prone Type III kerogens. These samples have low hydrocarbon potential as well. The samples that are prone to generating dry gas include several samples from the Silt, Clay, and Sand formation, as well as from the Channel Fill and Triassic Breccias and Shale Fragments formations. One sample from the Mudstone Slope formation appears to be the only data point in this group with the highest hydrocarbon potential. There are a few samples that are categorized as an oil prone Type I kerogen from lacustrine environments – these are from the Undifferentiated Posidonia Beds and Lower Posidonia Beds. The single sample from the Undifferentiated Posidonia Beds in the Type I kerogen category also has high hydrocarbon potential. The samples in the Type II category include: the Vigla Shales, Posidonia Beds, Undifferentiated Posidonia Beds, Upper Posidonia Beds, Lower Posidonia Beds, Triassic Breccias and Shale Fragments, and Sapropel formations. There are a number of these samples that also appear to have very high hydrocarbon potential, such as samples from the Undifferentiated Posidonia Beds, Vigla Shales, Posidonia Beds, and Sapropel formations.

Figure 23 shows the same results for the S2 parameter versus the TOC arranged by the age of the sample. According to this plot, the majority of the younger formations from the Oligocene, Neogene, Miocene, and Pliocene are classified as Type II/Type III, Type III, and dry gas prone kerogens. The formations that are located in the oil prone Type II kerogen category are mostly the older formations from the Triassic, Jurassic, and Cretaceous periods, although there are a few samples from the Miocene that are also in this category. The samples that have high hydrocarbon potential in this category are mostly Jurassic, though there are two samples from the Triassic period and three samples from the Miocene that have high hydrocarbon potential as well. The samples that are located in the oil prone Type I category all date back to the Jurassic. One sample in particular has high hydrocarbon potential.

In comparing both Figure 22 and Figure 23, it is possible to observe that the samples more disposed to develop oil and have higher hydrocarbon potential are the older samples from the Triassic, Jurassic, and Cretaceous periods (the Vigla Shales, Posidonia Beds, Undifferentiated Posidonia Beds, Upper Posidonia Beds, Lower Posidonia Beds, and Triassic Breccias and Shale Fragments formations). In addition, it is possible to observe that the younger samples from the Oligocene, Neogene, Miocene, and Pliocene (which correspond to the Mudstone Slope, Channel Fill, Silt, Clay, and Sand, and Sediment and Alluvial Deposits formations) – are more prone to developing gas than oil, and have a lower hydrocarbon potential.

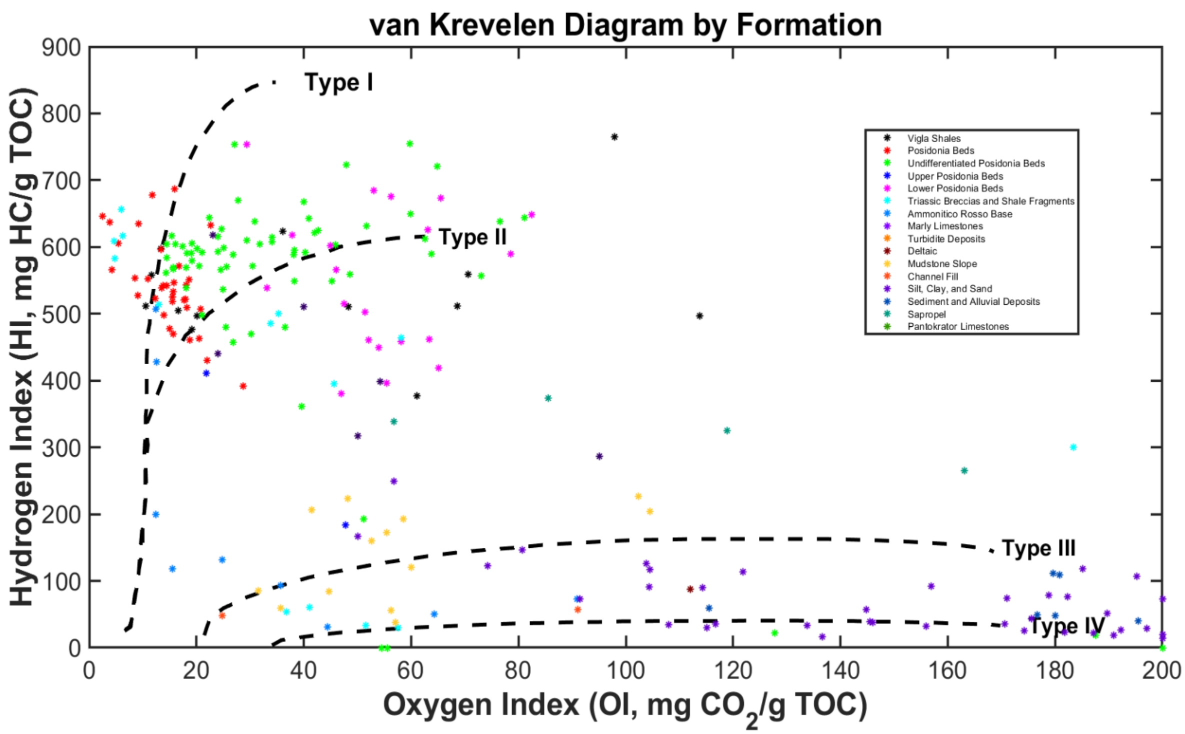

Figure 24 – Rock-Eval Pyrolysis Results for van Krevelen Diagram According to Formation

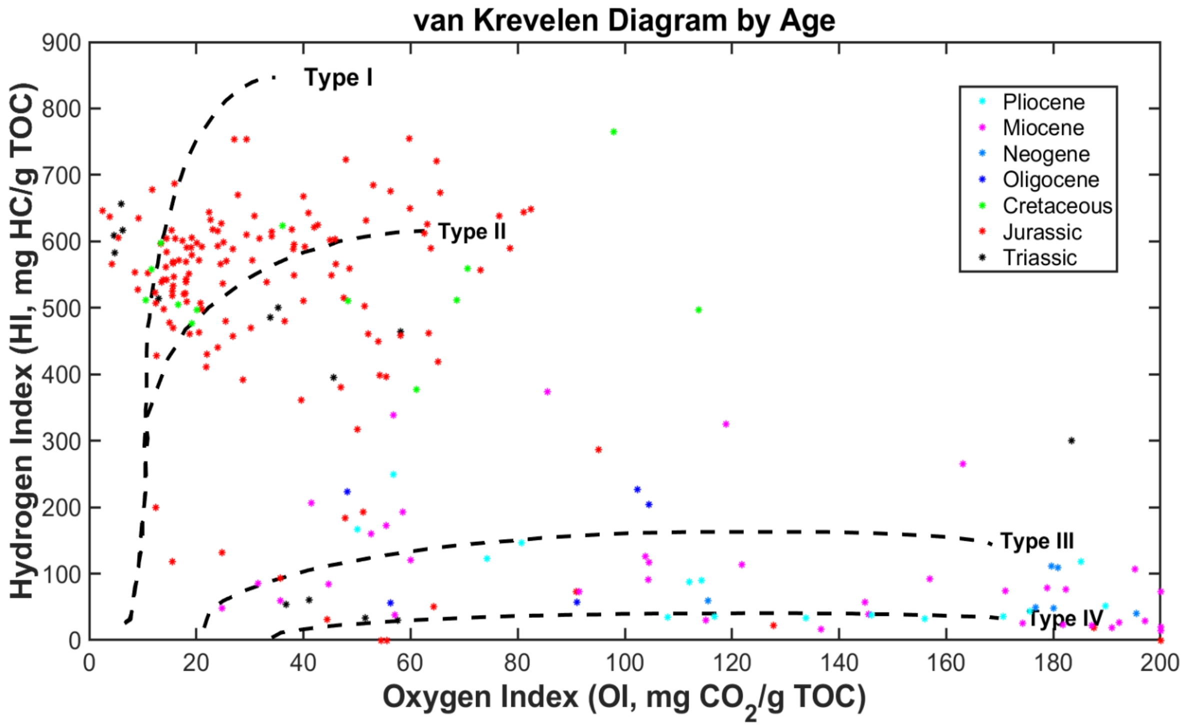

Figure 25 – Rock-Eval Pyrolysis Results for van Krevelen Diagram According to Age

The last two set of charts created for analyzing the Rock-Eval pyrolysis data are van Krevelen diagrams, which graph the hydrogen index (HI) versus the oxygen index (OI). This graph also indicates the type of kerogen of the sample. The value of the HI and OI increases as the maturity of the sample increases, which is reflected in the diagram as data points located closer to the origin of the graph (Tissot *et al*., 1985). Figure 24 shows the results of the van Krevelen diagram according to the formation type of the samples. According to this image, the majority of the samples tend to be Type I or Type II kerogens, including samples from the Vigla Shales, Posidonia Beds, Undifferentiated Posidonia Beds, Upper Posidonia Beds, Lower Posidonia Beds, Triassic Breccias and Shale Fragments formations. The samples that are Type III and Type IV kerogens include the Mudstone Slope, Channel Fill, Sediment and Alluvial Deposits, and Silt, Clay, and Sand formations. In addition, there is some degree of overlap due to a small number of samples from other formations deviating from the general pattern of the whole group. For example, several samples from the Triassic Breccias and Shale Fragments formation are located in the Type III and Type IV regions of the diagram. These observations match the results of previous charts for the type of kerogen present among the samples.

Figure 25 displays the results for the van Krevelen diagram according to the age of the samples. The samples categorized in the Type I and Type II category are the older samples from the Triassic, Jurassic, and Cretaceous periods. The Type III and Type IV samples consist mainly of the younger samples that date back to the Oligocene, Neogene, Miocene, and Pliocene. Some of the individual data points in these two kerogen categories are part of the older formations; the Triassic and Jurassic each have a small number of samples that are Type III and Type IV. As with Figure 24, these results are also similar to those of previous charts for kerogen type. Both Figure 24 and Figure 25 exhibit similar results to the previous charts in that the Type I and Type II kerogens are the older formations, while the Type III and Type IV kerogens are the younger formations.

Alkanes

The alkanes data from the diploma theses was also plotted in MATLAB to create bar charts and box plots. There are sixty-eight samples in the alkanes data set that were used in this research – this data includes information on the composition of the sample, particularly on the hydrocarbon components present, from components C_{14} through C_{35}. The values of these components can determine the environment of deposition of the samples. For example, high values of components up to C_{20} indicate that the organic matter originated in a marine environment or due to bacteria, while high values of components between C_{20} and C_{35} indicate that the organic matter was originally deposited in a terrigenous environment. The boxplots that were created for each of the components in the alkanes data can be reviewed in the Appendix. These box plots are meant to illustrate the distribution of each type of component. There is little difference between the original box plots and the normalized box plots – thus the normalized box plots were used. As seen in these images in the Appendix, none of the components exhibit a normal distribution of the data from the samples, though the box plot for C_{34} appears to be closer to a normal distribution in comparison to the other components. In addition, it must be noted that the extreme values are unequally distanced from the median, once more indicating a lack of a normal distribution of the data. The following figures are the results of the bar charts, arranged by diploma thesis and by age of the samples.

These figures have been normalized to illustrate the distribution of the data. The original plots can be seen in the Appendix**.**

The data was first arranged by diploma thesis and titled according to the dominant formations of the samples. Figure 26 below shows the data obtained from Klokotini 2015 – this data is mainly from the Pantokrator Limestones. Samples DRAG1-3 and KOKKINO are from turbidite deposits and the Posidonia Beds, respectively. The samples used in this diploma thesis were collected from locations in western Greece – more specifically, from the Epirus region of western Greece. DRAG 1-4 was obtained from Dragopsa; KOKKINO was obtained from Kokkino Lithari; ELAT 1-1, ELAT 1-2, ELAT 1-3, ELAT 1-4, ELAT 2-1, and ELAT 2-2 were collected in Elataria; lastly, GIRO 1-1 and GIRO 2-1 were attained in Giromeri. The unusually high value of C_{28} in KOKKINO is likely a result of human error, though it is expected that the result will not affect the dendrogram.

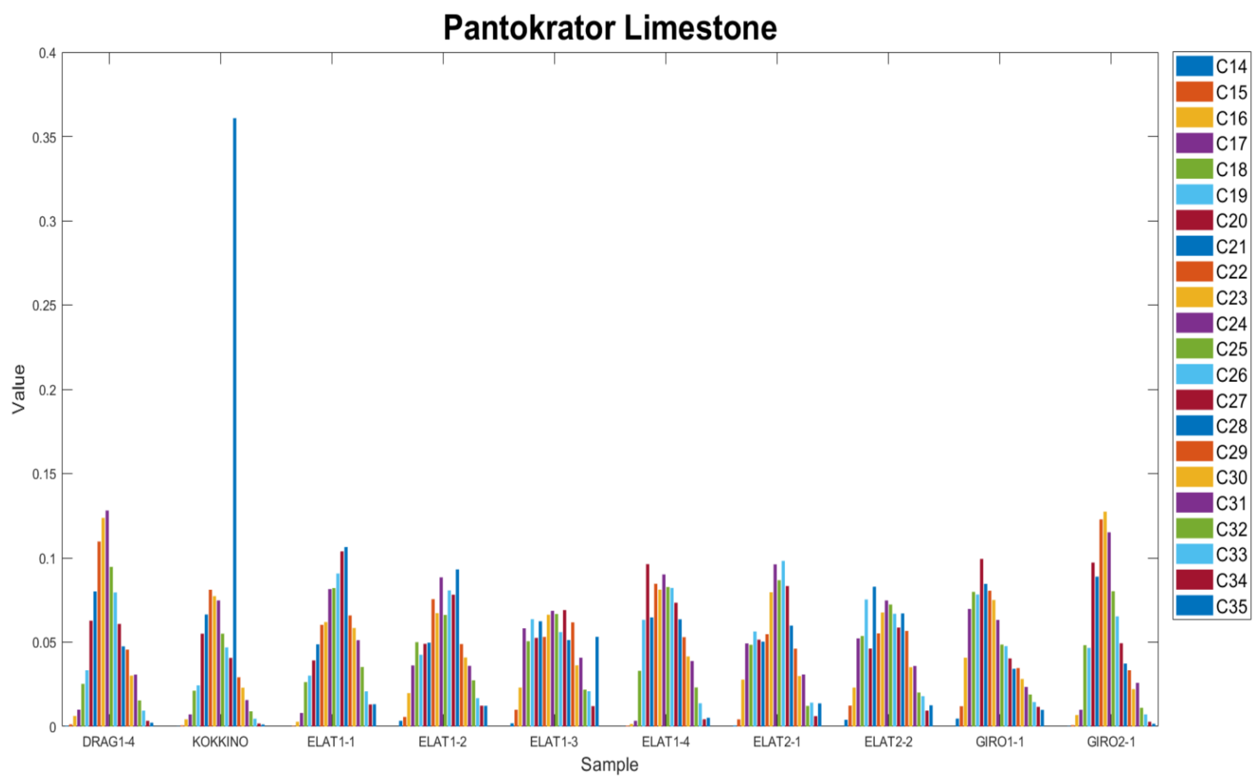

Figure 26 - Bar Chart of Data from the Diploma Thesis of Klokotini 2015

Figure 27 below shows the data obtained from the diploma thesis written by Papoulas 2016. All of the samples used in this study were taken from sediment and alluvial deposits on Kefalonia, a large island in western Greece. The unusually high value of C_{31} in KAL_89 is likely a result of human error that occurred during experimentation.

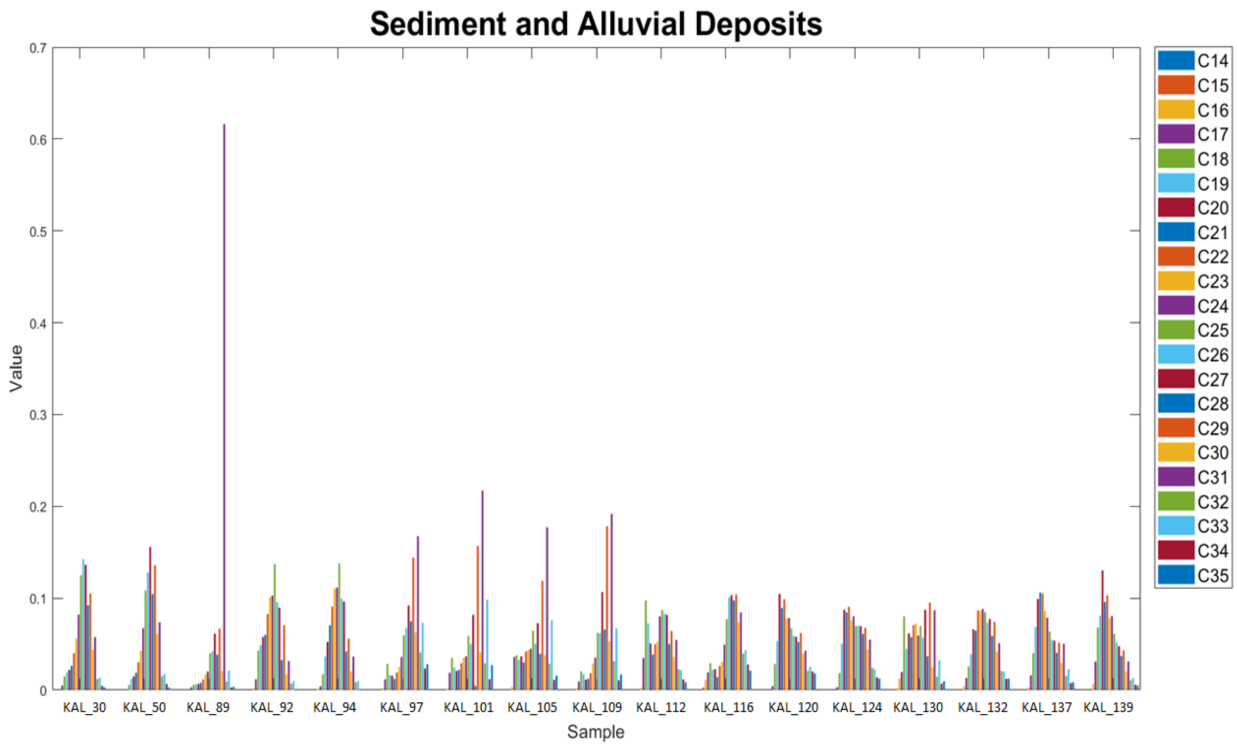

Figure 27 - Bar Chart of Data from the Diploma Thesis of Papoulas 2016

The following Figure 28 shows the results for data collected from the diploma thesis written by Tsochantaris 2017. All of the samples consist of a combination of silt, clay, and sand, and originate from a region called Agios Georgios in northwestern Corfu, an island in northwestern Greece close to the border with Albania.

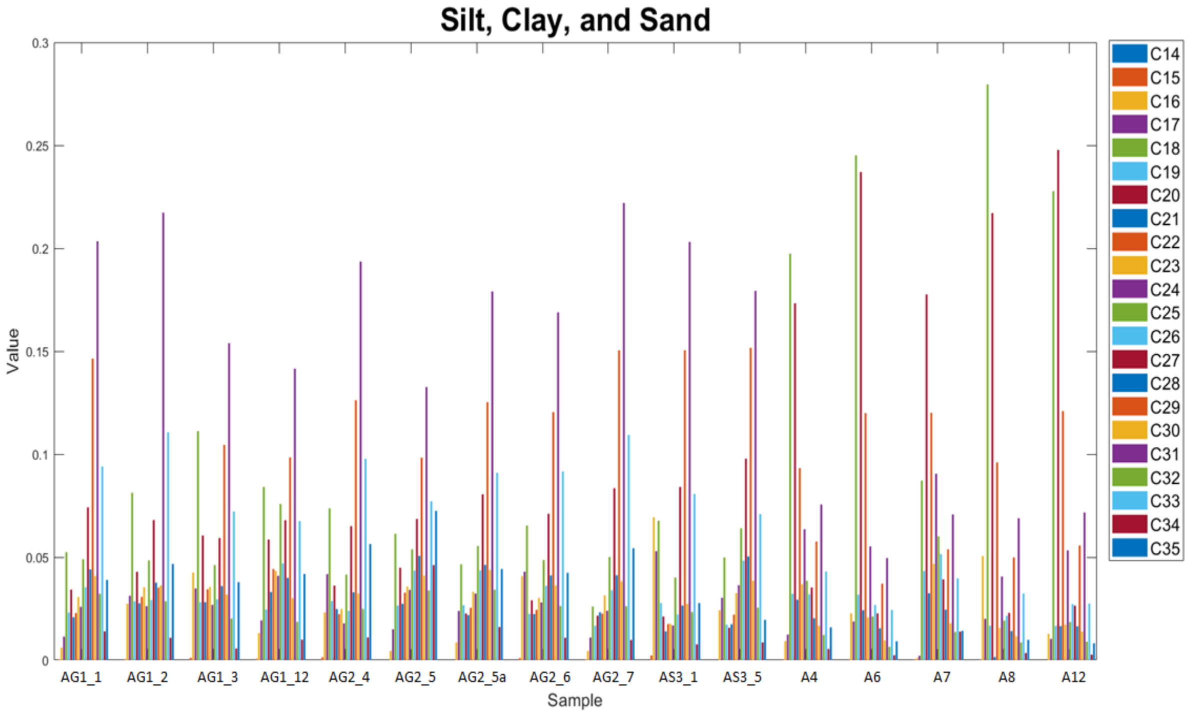

Figure 28 - Bar Chart of Data from the Diploma Thesis of Tsochantaris 2017

The next image displays the results of data taken from the diploma thesis written by Koukounya 2014. These samples include a mix of silt, clay, and sand; samples Z1, Z2, Z3, and Z4 are from Sapropel formations, and Z5 consists of a combination of silt, clay and sand. Samples Z6, Z7, Z8, Z9, Z12, and Z13 consist of a mix of clay and sand; samples Z14, Z15, Z16, and Z17 are made up of a combination of silt, clay, sand, and slumps. Samples Z18, Z19, Z20, and Z21 are, like Z5, a mix of silt, clay, and sand. The remaining samples (Z22, Z23, Z24, Z25, Z26, and Z27) consist of silt and evaporites. All of the samples are from Zakynthos Island in western Greece. There are several instances of very high values of C_{31} in this grouping – the most extreme values are likely the result of human error during experimentation.

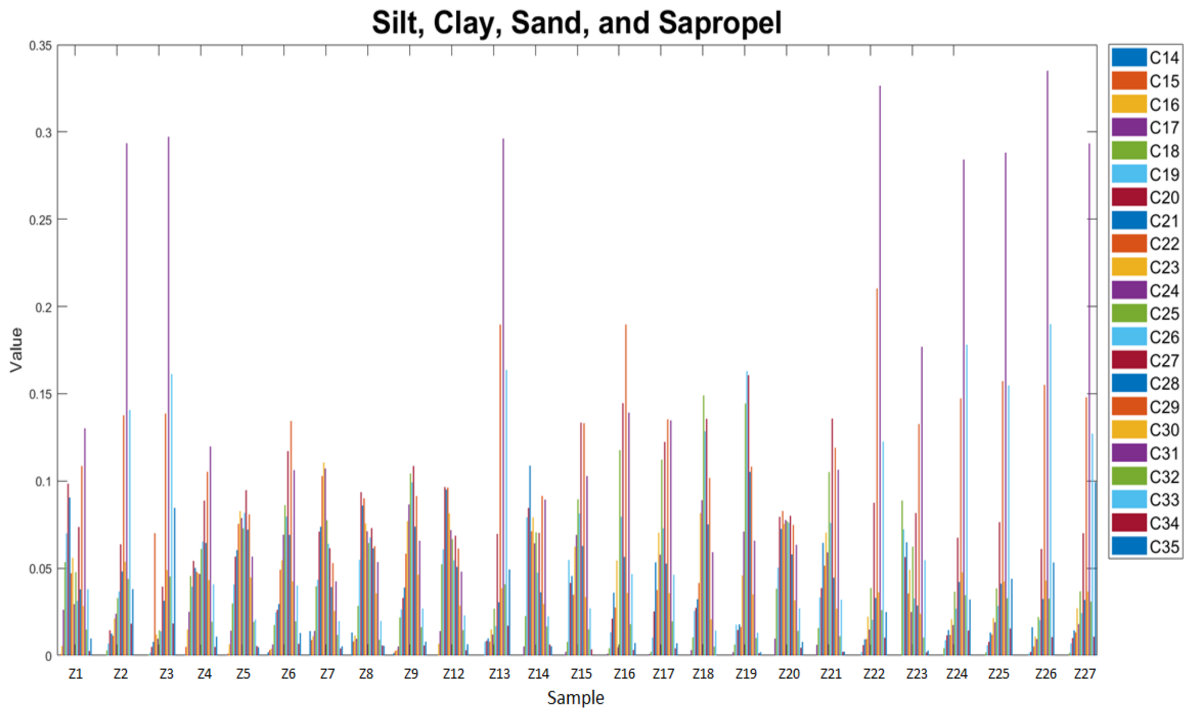

Figure 29 - Bar Chart of Data from the Diploma Thesis of Koukounya 2014

The following images show the same results as Figures 26 through 29, however, all of the data has been arranged according to the age of the sample. Figure 30 below shows the results for the components of samples from the Jurassic period. There is an outlier in the C_{28} component of the sample KOKKINO, which as previously mentioned may be attributed to error during analysis. Overall, there appears to be the general pattern of smaller values of the lighter and heaver components, and higher values of the other components. The sample named KOKKINO appears to have higher values of C_{20} to C_{24}, not including the value of C_{28}. The sample named ELAT 1-1 shows high values of components C_{26} to C_{28}; ELAT 1-2 shows peaks at C_{24} and C_{28}; ELAT1-3 plateaus somewhat between C_{17} and C_{29}, with a higher value of component C_{35}; ELAT 1-4 has higher values between C_{19} and C_{27}; ELAT 2-1 shows higher values between C_{23} and C_{27}; and ELAT 2-2 has the highest values at components C_{19} and C_{21}. The sample GIRO 1-1 peaks between C_{17} and C_{24} at component C_{20}, while the values for GIRO 2-1 peak between C_{20} and C_{24}. By examining these values, it appears that the samples KOKKINO, ELAT1-1, ELAT 1-2, ELAT 2-1, and GIRO 2-1 have the highest values between components C_{20} and C_{28}, indicating that they may be terrigenous in origin. ELAT 2-2 is more inconclusive, although the high value of C_{35} may indicate a terrestrial influence. ELAT 1-4 and GIRO 1-1 appear to have the highest values around C_{20}, which also implies a terrestrial origin.

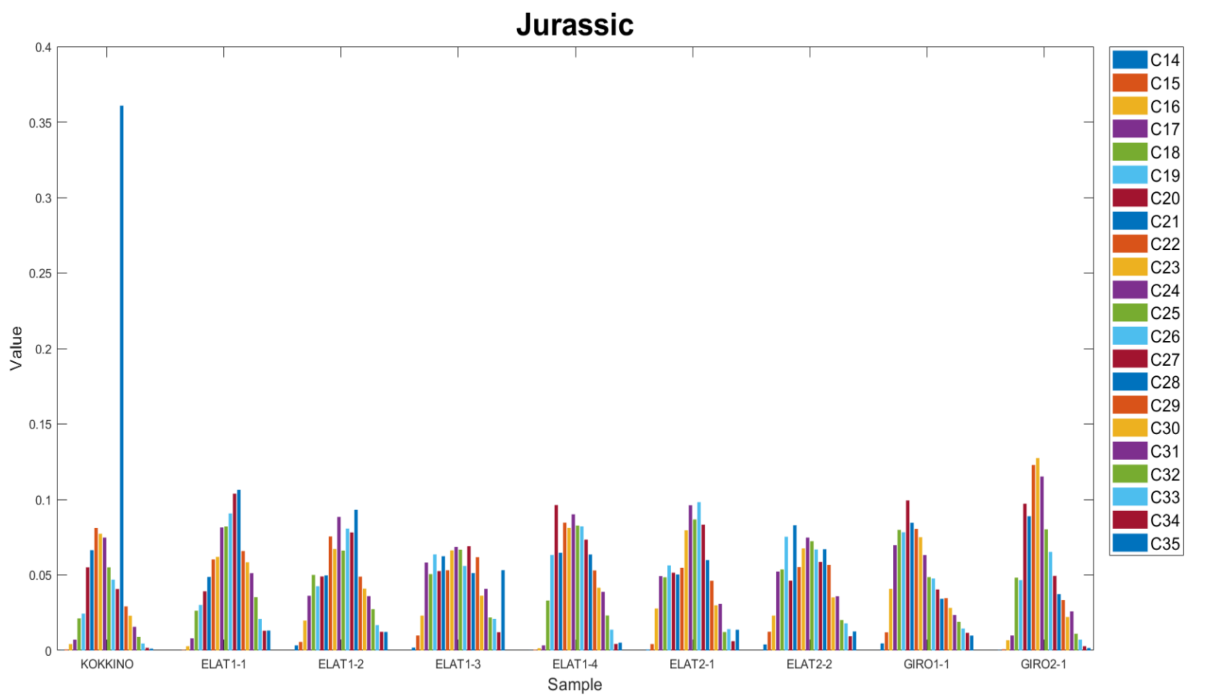

Figure 30 - Bar Chart of Alkanes for Samples from the Jurassic

Figure 31 below shows the results of the components for samples from the Oligocene epoch. The sample Z13 appears to have very high values for the C_{29}, C_{31}, and C_{33} components, especially for the C_{31} component, which may be due to human error during experimentation. The sample Z14 does not reflect the same pattern – the lighter components, especially C_{19} to C_{21}, are higher in value, although components C_{29} and C_{31} have higher values than the rest of the heavy components. Sample Z15 has high values for components C_{27}, C_{29}, and C_{31}. Z16 has high values between C_{25} and C_{31}, especially for component C_{29}; however, C_{24} appears to have a very low value. Sample Z17 has the highest values for components C_{25}, C_{27}, C_{29}, and C_{31}. All of the samples from the Oligocene tend to have higher values for the heavier components, indicating the possibility of sample origin in a terrigenous environment. It must be noted that sample Z14 is slightly different in that its highest value is the C_{21} component.

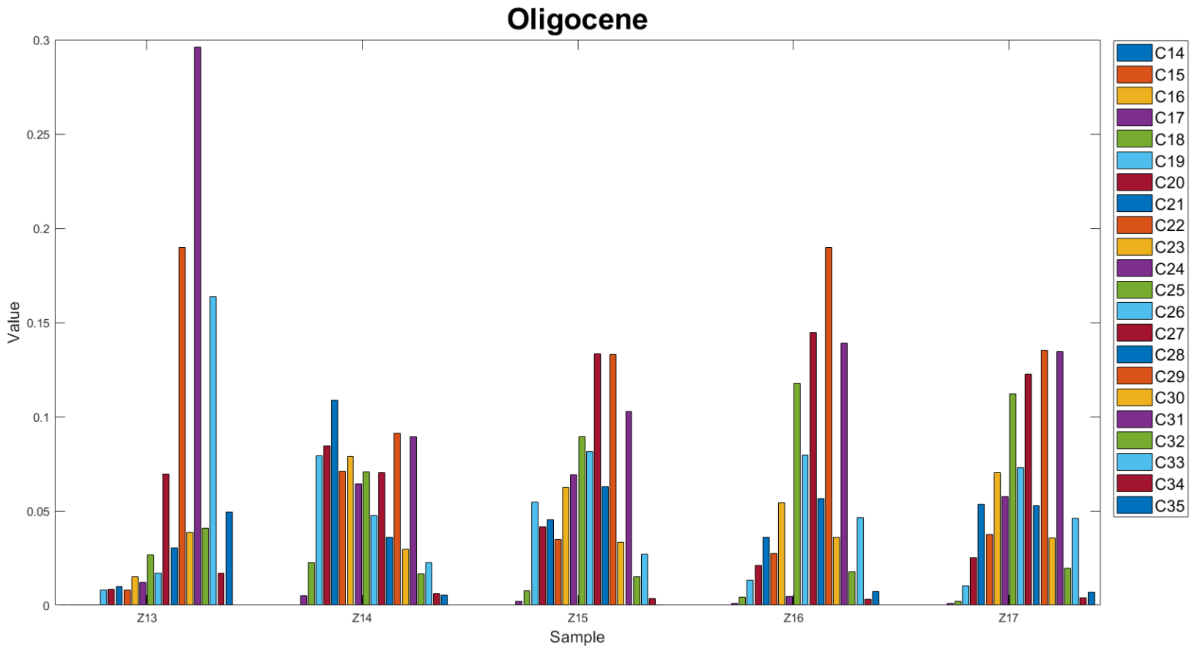

Figure 31 - Bar Chart of Alkanes for Samples from the Oligocene

The next image, Figure 32, shows the normalized plot of the alkanes data from the Neogene period. There is an outlier in sample KAL_89 regarding component C_{31}, which may be due to human error. Sample KAL_30 has high values between C_{24} and C_{29}; KAL_50 has high values between components C_{25} and C_{29}; sample KAL_89 peaks at C_{27} and C_{29}, with the exception of the outlier at C_{31}; and KAL_92 has high values between components C_{23} and C_{27}. Sample KAL_94 also peaks between C_{23} and C_{27}; KAL_101 has high values for components C_{29} and C_{31}, with an unusually low value for C_{28}. Samples KAL_105 and KAL_109 both have high values for components C_{29} and C_{31}. KAL_112 follows a slightly different pattern – the highest value is component C_{18}, with another peak from C_{24} to C_{27}. KAL_116 has high values between C_{25} and C_{31}; however, samples KAL_120 and KAL_124 peak at components C_{20} and C_{22}. Sample KAL_130 has high values for components C_{18}, C_{27}, C_{29}, and C_{31}; KAL_132 has high values between C_{22} and C_{27}; sample KAL_137 has high values between C_{20} and C_{22}; and lastly, sample KAL_139 peaks at component C_{20} and at component C_{22}. After examining these samples, it is apparent that most of the Neogene samples follow the general trend of having greater values of components between C_{23} and C_{31} – this implies that these samples originate in an onshore environment. The samples that have the highest values between C_{14} and C_{20} – KAL_112, KAL_120, KAL_130, KAL_137, and KAL_139 – indicate the possibility of a marine or bacterial influence at the time of organic matter deposition; however since the heavier components are also prevalent, this makes such a possibility unlikely.

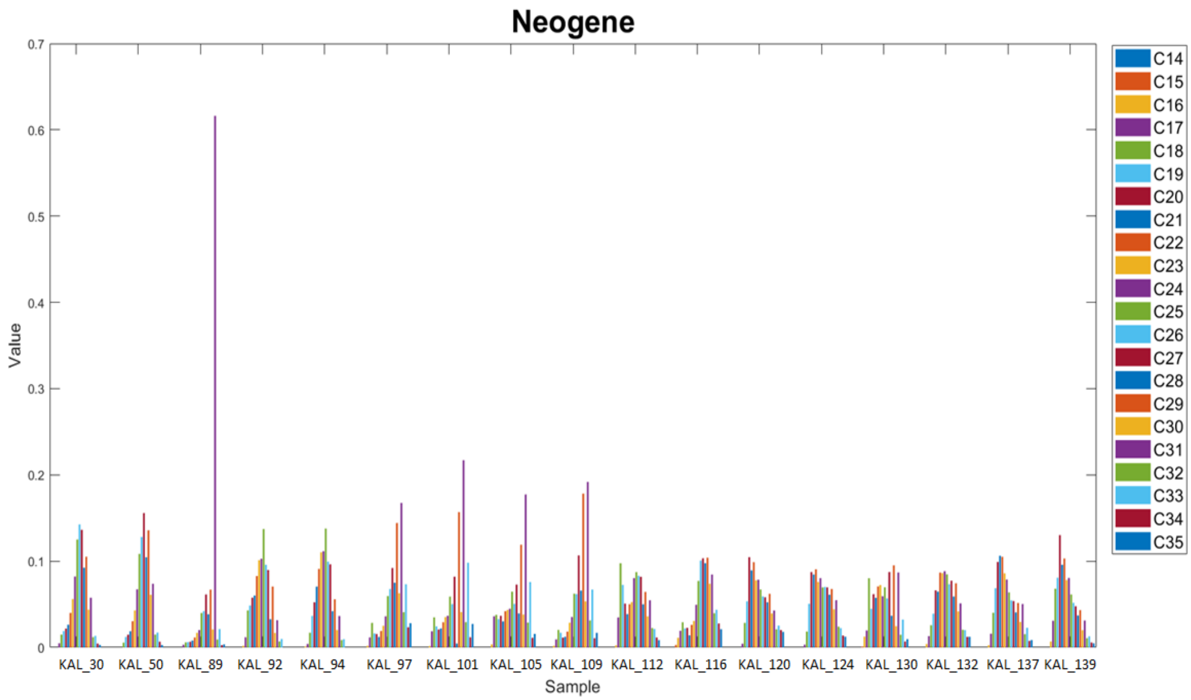

Figure 32 - Bar Chart of Alkanes for Samples from the Neogene

The following Figure 33 shows the results for samples that date back to the Miocene. Sample AG1_1 has the highest values at components C_{27}, C_{29}, C_{31}, and C_{33}, with another smaller peak at component C_{18}. AG1_2 has high values at C_{31}, C_{33}, and a smaller peak at C_{18}; sample AG1_3 peaks at component C_{31}, with the next highest values at C_{18} and C_{29}. The highest values in sample AG1_12 are at C_{29} and C_{31}, with the next highest component at C18; for sample AG2_4, the highest components are C_{29}, C_{31}, C_{33}, and C_{18}. Samples AG2_5, AG2_5a, and AG2_6 all have high values at components C_{27}, C_{29}, C_{31}, C_{33}, C_{35}, and C_{18}; however, while sample AG2_7 shows C_{27}, C_{29}, C_{31}, C_{33}, and C_{35} as the highest value components, the value of C_{18} is the smallest in comparison to that of all of the other samples. In comparison to the previous images, it is apparent that there is a pattern to the data plotted in Figure 33. All of the samples have component C_{31} as the highest component, closely followed by C_{29} and C_{33}. This implies that all of the samples from the Miocene are terrigenous in origin.

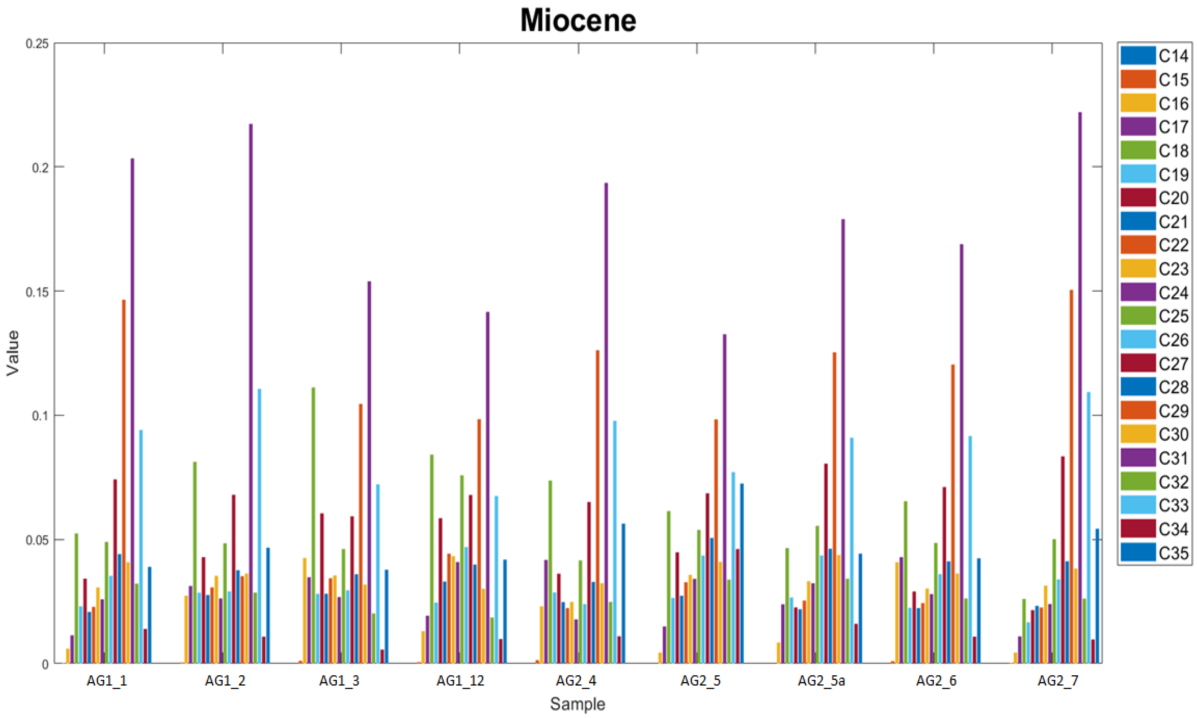

Figure 33 - Bar Chart of Alkanes for Samples from the Miocene

Figure 34 below shows the alkanes data plotted for the samples from the Late Miocene. There are two outliers that belong to component C_{31} of samples Z2 and Z3 – these outliers may also be due to human error during experimentation. Sample DRAG 1-4 appears to have the highest component values at C_{22}, C_{23}, and C_{24}. Sample Z1 has the highest peak at component C_{31}, followed by C_{29}, C_{20}, and C_{21}. For samples Z2 and Z3, the highest peaks other than the outlier at C_{31} are at components C_{29} and C_{33}; it must be noted that component C_{22} of Z3 is also a point of interest. Sample Z4 has the highest component values at C_{31}, C_{29}, and C_{27}; sample Z5 peaks at C_{27}, though the values of components C_{22} through C_{29} are also quite high. Sample Z6 has high values for components C_{29}, C_{27}, and C_{31}; sample Z7 peaks at C_{22} through C_{24}; and sample Z8 has high values starting at component C_{20}, followed by components C_{22} and C_{21}. Sample Z9 has high values for components C_{25}, C_{26}, C_{27}, and C_{29}; sample Z12 exhibits three peaks with similar values at components C_{20}, C_{21}, and C_{22}. Sample Z18 has high component values for C_{25}, C_{26}, C_{27}, and C_{29}; and lastly, sample Z19 peaks at components C_{25}, C_{26}, C_{27}, C_{28}, and C_{29}. The samples in Figure 34 appear to have a general trend of higher component values between C_{25} and C_{31}, which indicates that these samples are likely terrestrial in origin.

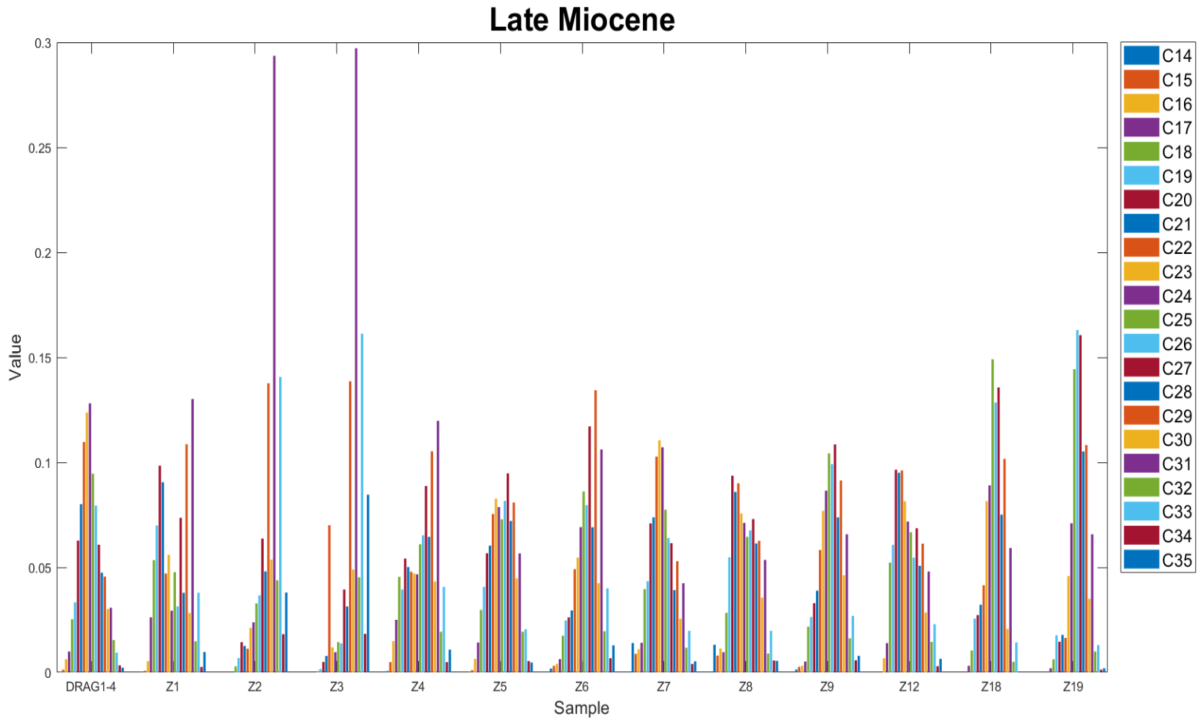

Figure 34 - Bar Chart of Alkanes for Samples from the Late Miocene

Figure 35 below shows the results for alkanes data of samples from the Early Pliocene. Sample Z20 appears to have the highest component values between C_{20} and C_{29}, while sample Z21 has a number of significant peaks at components C_{25}, C_{27}, C_{29}, and C_{31}. Sample Z22 has the highest peak at C_{31}, which may be due to human error; however, components C_{29}, C_{33}, and C_{27} are also significant. The highest component value in sample Z23 is at C_{31}, followed by C_{29}, C_{18}, and C_{27}. Samples Z24, Z25, Z26, and Z27 all have very high values of component C_{31}, which – as in sample Z22 – may be due to human error; in addition, all of these samples have high values of components C_{29} and C_{33}. It can be observed that the C_{35} component in sample Z27 is higher in comparison to the previous samples. There appears to be an overall pattern among the samples from the Early Pliocene. Most of the samples have high values of components C_{29}, C_{31}, and C_{33}, which implies that the majority of the samples from the Early Pliocene originate from a terrigenous environment.

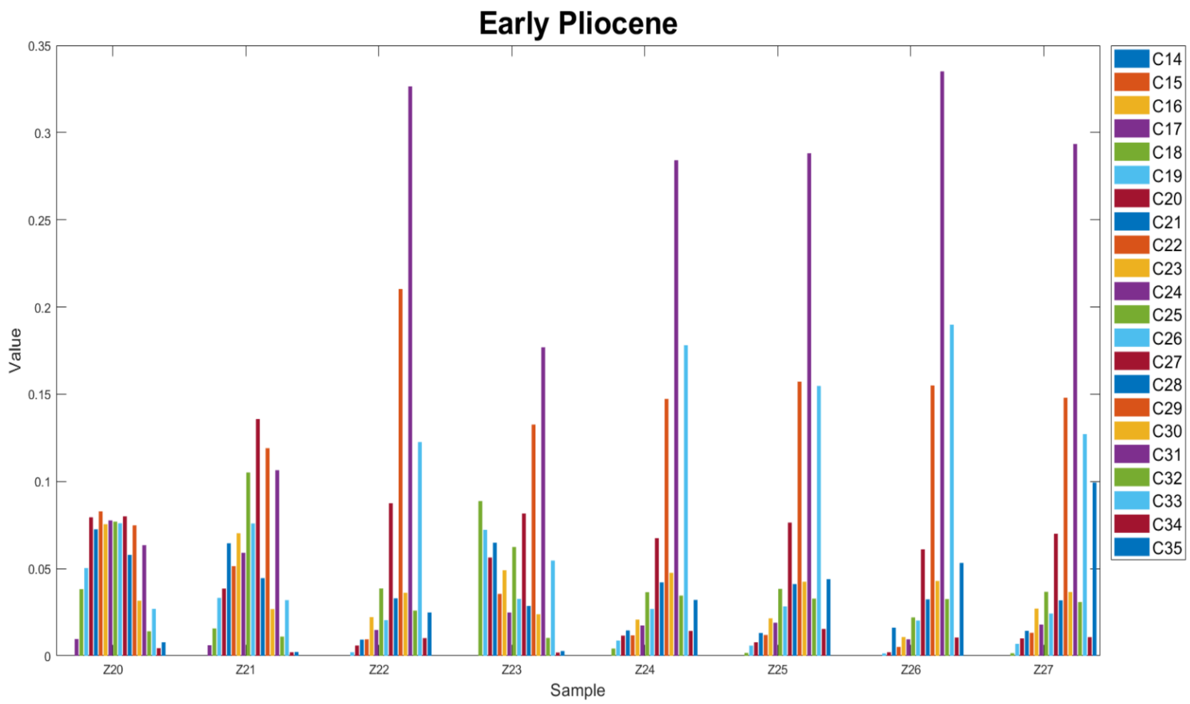

Figure 35 - Bar Chart of Alkanes for Samples from the Early Pliocene

The final image, Figure 36 below, displays the results of the alkanes data for samples from the Pliocene. Sample AS3_1 has several high values of components, including components C_{31}, C_{29}, C_{27}, C_{33}, C_{16}, and C_{18}. Sample AS3_5 follows a similar pattern as sample AS3_1 – the highest values are at components C_{31}, C_{29}, C_{27}, C_{25}, C_{33}, and C_{18}. Samples A4, A6, A8, and A12 have peaks at components C_{18} and C_{20}, followed by a smaller peak at component C_{22}. Sample A7 is somewhat different in that the highest value is at component C_{20}, followed by peaks at C_{22}, C_{24}, and C_{18}. Samples AS3_1 and AS3_5 appear to be the only samples in this group with high values of components C_{27}, C_{29}, C_{31}, and C_{33}, indicating that they are likely originally from a terrigenous environment. The rest of the samples – A4, A6, A7, A8, and A12 – all have the highest values at components C_{18} and C_{20} (except in the case of sample A7, in which component C_{20} is greater than C_{18}). This implies that these samples were under marine or bacterial influence during the time of deposition. However, this may not be the case for sample A7, due to its high value of C_{20}; therefore, it is likely that A7 originated in a terrigenous environment.

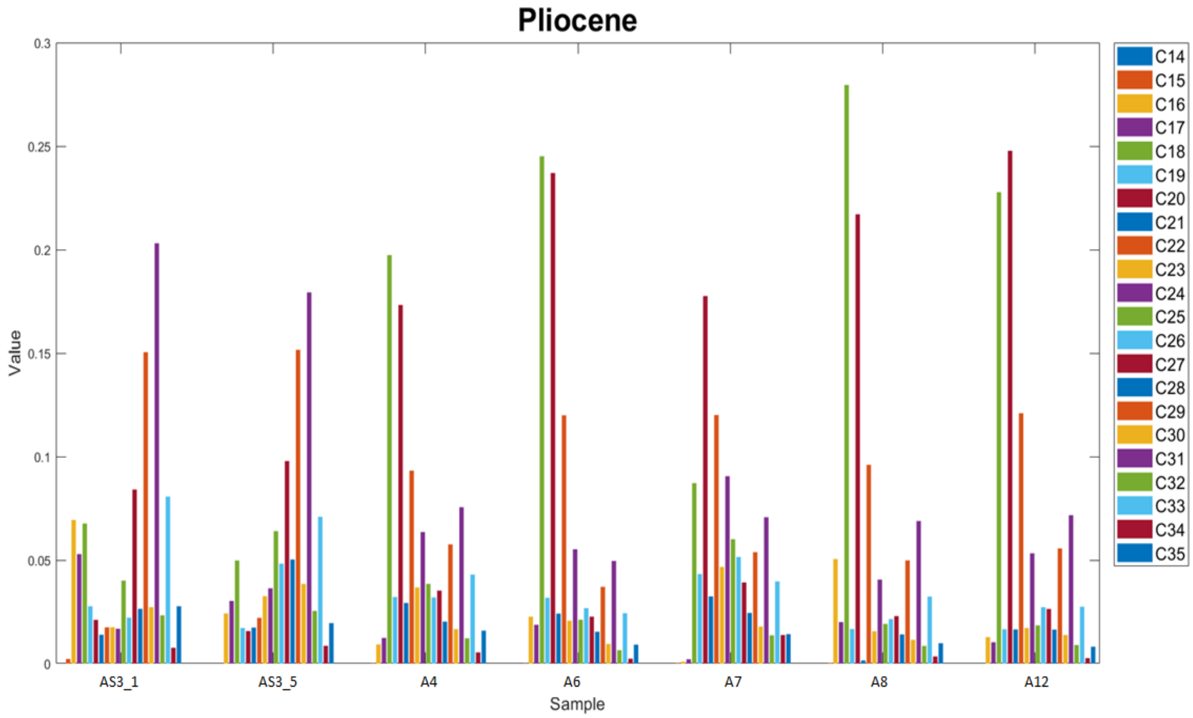

Figure 36 - Bar Chart of Alkanes for Samples from the Pliocene

In addition to the bar charts and box plots, a dendrogram was created by normalizing the alkanes data and performing hierarchical clustering using the Euclidean distance between the data points with the average linkage function. The results can be seen in Figure 37 below. According to this dendrogram, there appears to be two main oil families. One oil family is much smaller and consists of samples A4, A6, A12, and A8, while the other oil family consists of the rest of the samples in the alkanes data set. This larger oil family has two smaller sub-families, and each sub-family has two more subsets. It is likely that samples A4, A6, A12, and A8 are separate from the other samples due to their probable origins in a marine environment. It can be assumed that the rest of the grouping for the dendrogram are arranged according to the values of the components of the samples. There may be a relationship among the samples according to the quantity of heavy components in the hydrocarbon samples. For example, the first subset on the left, consisting of samples Z24, Z25, Z2, Z13, Z26, Z27, Z22, Z3 have very high values of component C31, implying a relationship among these samples. It is likely that these four smaller groups in the larger oil family of terrestrial origin are grouped according to the original depositional environment. The clustering does not appear to reflect any patterns according to age or location, therefore it is likely that the grouping is according to variations in the original depositional environment. This indicates the possibility that the oil family originating in terrestrial environments has four smaller oil families with varying conditions of terrestrial environments. According to these observations, all of these samples from the alkanes data set were grouped according to the original environment of deposition. Thus, it is appropriate to assume that the two major oil families are differentiated by their origins in terrestrial and marine environments.

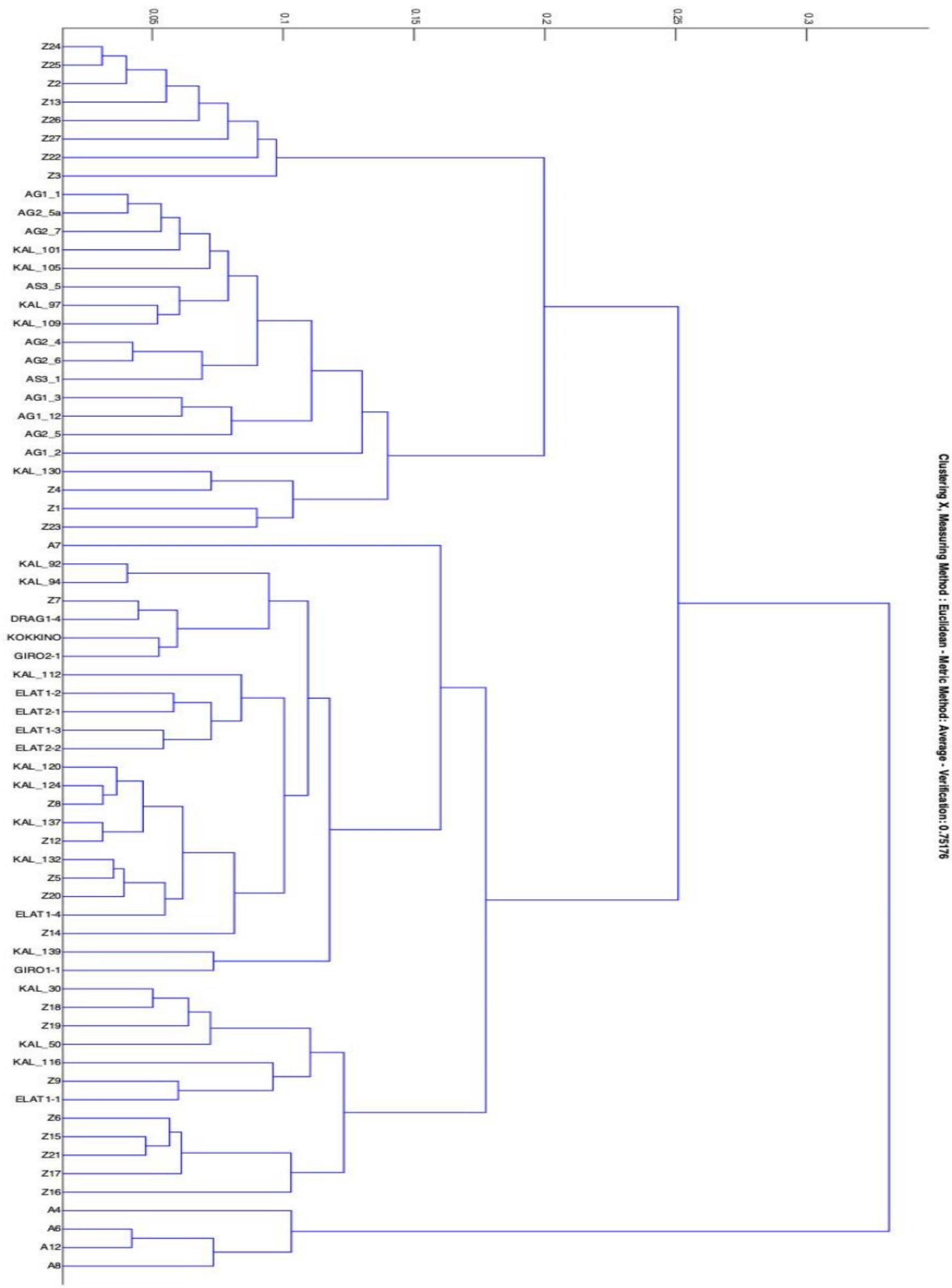

Figure 37 - Dendrogram of the Alkanes Data

Conclusions

There are two main objectives of this research – first, to collect all available data regarding extracts and core samples taken from western Greece in order to establish a collective database for future research. The available data was partitioned into separate data sets according to the type of data. The second objective is to conduct analyses on the available data; in this case, the Rock-Eval pyrolysis results and the alkanes data are the most complete and thus have the potential to determine the possibility of a relationship among the various samples collected.

The Rock-Eval pyrolysis was performed on more than three hundred samples from a variety of formations that date back to the Triassic through the Pliocene. Fourteen charts were created in total – seven charts according to the sample formation, and seven charts according to the age of the samples. These charts provide information regarding the data, such as kerogen type, maturity, dependability of the source, oil type classification, potential for hydrocarbon generation, and state of migration. Figures 12 through 25 display the results of the data graphed upon these charts. After examining these images, it was possible to reach several conclusions regarding the Rock-Eval pyrolysis data. Firstly, it appears that all of the samples are indigenous, meaning that they have not migrated very far from the source rock and have remained mostly uncontaminated. In addition, most of the samples are Type II kerogens that originate from marine environments; these samples tend to be from older formations that date back to the Triassic, Jurassic, and Cretaceous periods. Many of these samples have high potential for hydrocarbon generation. The majority of these Type II kerogens are also classified as being within the oil show window, with the oldest samples from the Triassic period within the oil window. These older Type II kerogens are also classified as good to excellent oil sources, implying that the best source rocks are the oldest formations in western Greece, particularly in the Ionian zone. Type I kerogens in this case are rarer and less likely to occur.

The remaining samples can be categorized as Type III and Type IV kerogens. According to Figures 12 through 25, these Type III and Type IV kerogens tend to be members of the youngest formations from the Neogene period; more specifically from the Oligocene through the Pliocene epochs. These types of kerogen tend to originate from land-based organic matter such as plant debris. According to these figures, these samples are less mature and although they are classified as oil shows, they generally have low potential for hydrocarbon generation. It must be noted that these Type III and Type IV kerogens also tend to be very poor sources of hydrocarbons, indicating that the least dependable source rocks are the youngest formations in western Greece. Although the majority of these samples fall into either Type II or Type III/Type IV kerogens, some of the samples fitting the physical descriptions of these kerogens have turned out to be completely the opposite. For example, in Figures 18 and 19, samples from the Miocene – most of which have poor oil generation potential – can be found classified as having excellent potential for the generation of hydrocarbons. In addition, some of the samples from older formations of the Triassic and Jurassic periods can be described as Type III or Type IV kerogens, as seen in Figures 18, 19, 24, and 25. Due to this discrepancy, it may be appropriate to assume that there may be some degree of error in the data, or that the individual samples themselves have developed differently according to the environment in comparison to other samples fitting the same description.

There are sixty-eight samples of alkanes data in the database that have been used to create the bar charts and the dendrogram in the previous section, as well as the box plots provided as a reference in the Appendix. The bar charts were created according to the diploma thesis from which the samples were collected and by formation, as well as according to the age of the samples. The results indicate that there appears to be little correlation among the data where it is divided according to the diploma thesis and formation. However, the bar charts created according to age seem to exhibit some patterns in Figures 33, 35, and 36. These images display the results for samples from the Miocene, Early Pliocene, and Pliocene epochs. Most of the distributions of the component values for these samples have a similar shape, indicating the possibility of having a similar composition. The most significant observation was that the majority of the samples from the Pliocene had high values of C_{18}, which implies that the initial environment of deposition was likely marine, perhaps with a bacterial influence. The bulk of the alkanes data has high values for the heavier components, indicating that they are likely to have formed on land.

The dendrogram created from this data using hierarchical clustering also yielded some interesting results that can be supported by the bar charts. As seen in Figure 37, there appears to be two main clusters among the samples – one cluster is unusually large and includes most of the samples, while the other cluster is much smaller and consists of only a small number of samples. A more thorough examination of the dendrogram determined that the smaller cluster consists of samples that were determined by the bar charts to be marine in origin, thus indicating that the remaining samples are derived from a terrigenous environment. The most significant conclusion that may be made according to this data is that there are two oil families present among the samples with alkanes data. This in turn implies that the majority of the samples originated in a terrestrial environment and are likely all genetically related to one another. The larger cluster can be further divided into two more clusters, each with their own sub-group. This may be due to the value of the heavier components, indicating a relationship among the heavy components of the samples. These four groups of the terrestrial oil family are most likely categorized according to variations of the conditions of the original depositional environment.

It can be concluded that the Rock-Eval samples from older formations have good potential of being good oil sources, and that the alkanes samples appear to come from two main oil families in western Greece. It is recommended that further investigations on the data be conducted as more information is gathered from ongoing and future research on hydrocarbons in western Greece, in order to have a greater understanding of the origins and development of hydrocarbons in this region.

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Appendix

MATLAB Code

Rock-Eval Pyrolysis:

By Age:

```
%% HI_TMAX

Ro05=dlmread('./Type_Maturity/KerMat05Ro.txt',';');
Ro135=dlmread('./Type_Maturity/KerMat135Ro.txt',';');
LimL=dlmread('./Type_Maturity/KerMatLeftLimit.txt',';');
LimR=dlmread('./Type_Maturity/KerMatRightLimit.txt',';');
T_MI=dlmread('./Type_Maturity/KerMatTypeI.txt',';');
T_MII=dlmread('./Type_Maturity/KerMatTypeII.txt',';');
T_MIII=dlmread('./Type_Maturity/KerMatTypeIII.txt',';');

HIa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'L2:L15');
TMAXa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'G2:G15');
HIb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'L16:L159');
TMAXb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'G16:G159');
HIc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'L172:L185');
TMAXc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'G172:G185');
HId = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'L188:L197');
TMAXd = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'G188:G197');
HIe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'L198:L283');
TMAXe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'G198:G283');
HIf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'L289:L324');
TMAXf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'G289:G324');
HIg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'L325:L334');
TMAXg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'G325:G334');

figure
hold on

title('HI - Tmax by Age','FontName','Arial','FontWeight','bold','FontSize',25);
plot(Ro05(:,1),Ro05(:,2),'k','LineWidth',3,'LineSmoothing','on','LineStyle','--')
plot(Ro135(:,1),Ro135(:,2),'k','LineWidth',3,'LineSmoothing','on','LineStyle','--')
plot(LimL(:,1),LimL(:,2),'k','LineWidth',3,'LineStyle',':')
plot(LimR(:,1),LimR(:,2),'k','LineWidth',3,'LineStyle',':')
plot(T_MI(:,1),T_MI(:,2),'k','LineWidth',3,'LineSmoothing','on')
plot(T_MII(:,1),T_MII(:,2),'k','LineWidth',3,'LineSmoothing','on')
plot(T_MIII(:,1),T_MIII(:,2),'k','LineWidth',3,'LineSmoothing','on')

a=plot(TMAXa,HIa,'*','Color',[0 0 0], 'linewidth',1.05);
hold on
b=plot(TMAXb,HIb,'*','Color',[1 0 0], 'linewidth',1.05);
c=plot(TMAXc,HIc,'*','Color',[0 1 0], 'linewidth',1.05);
d=plot(TMAXd,HId,'*','Color',[0 0 1], 'linewidth',1.05);
e=plot(TMAXe,HIe,'*','Color',[1 0 1], 'linewidth',1.05);
f=plot(TMAXf,HIf,'*','Color',[0 1 1], 'linewidth',1.05);
g=plot(TMAXg,HIg,'*','Color',[0 0.5 1], 'linewidth',1.05);

set(gca, 'box', 'on', 'linewidth', 2,'Fontname', 'arial','FontSize', 20)
ylim([0 1000])
xlim([350 550])

text(355,140,'Type III','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
```

```
text(355,110,'Oil/Gas Prone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(375,650,'Type II','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(375,620,'Oil Prone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(375,590,'(Usually Marine)','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0
0 0]);
text(385,910,'Type I','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(385,880,'Oil Prone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(385,850,'Usually Lacustrine','Fontname',
'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(400,970,'Immature','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(445,970,'Mature','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(440,940,'(Oil Window)','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(485,970,'Postmature','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(460,730,'0.5% Ro','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(475,180,'1.35% Ro','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(475,470,'Condensate-Wet Gas Window','Fontname',
'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(485,130,'Dry Gas Window','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);

xlabel('T_m_a_x (C^o)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)
ylabel('Hydrogen Index (HI, mg HC/g TOC)','Fontname', 'arial','FontWeight','bold','FontSize',24)

legend([f e g d c b a], 'Pliocene', 'Miocene', 'Neogene', ...
    'Oligocene', 'Cretaceous', 'Jurassic', 'Triassic');




%% HI_TOC
L1=[0.3 10;0.3 90];
L2=[0.64 30;100 30];
L3=[0.1 90;1.05 90];
L4=[0.17 180;1.06 180];
L5=[0.38 395;1.065 395];
L6=[0.63 30;100 3800];
L7=[1.05 90;100 6000];
L8=[1.06 180;71 10000];
L9=[1.065 395;34 10000];
L10=[0.1 105;9.4 10000];

figure
hold on

HIa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'L2:L15');
TOCa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K2:K15');
HIb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'L16:L165');
TOCb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K16:K165');
HIc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'L172:L186');
TOCc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K172:K186');
HId = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'L188:L197');
TOCd = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K188:K197');
HIe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'L198:L287');
TOCe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K198:K287');
HIf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'L289:L324');
TOCf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K289:K324');
HIg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'L325:L342');
TOCg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K325:K342');

plot(L1(:,1),L1(:,2),'k','LineWidth',1.5)
plot(L2(:,1),L2(:,2),'k','LineWidth',1.5)
plot(L3(:,1),L3(:,2),'k','LineWidth',1.5)
plot(L4(:,1),L4(:,2),'k','LineWidth',1.5)
plot(L5(:,1),L5(:,2),'k','LineWidth',1.5)
plot(L6(:,1),L6(:,2),'k','LineWidth',1.5)
plot(L7(:,1),L7(:,2),'k','LineWidth',1.5)
plot(L8(:,1),L8(:,2),'k','LineWidth',1.5)
plot(L9(:,1),L9(:,2),'k','LineWidth',1.5)
```

```
plot(L10(:,1),L10(:,2),'k','LineWidth',1.5)

set(gca,'XScale','log','box', 'on', 'Fontname', 'arial','FontSize', 20)
set(gca,'YScale','log','box', 'on','Fontname', 'arial', 'FontSize', 20)

axis on
ylim([10 10000])
xlim([0.1 100])

a=plot(TOCa,HIa,'*','Color',[0 0 0], 'linewidth',1.05);
hold on
b=plot(TOCb,HIb,'*','Color',[1 0 0], 'linewidth',1.05);
c=plot(TOCc,HIc,'*','Color',[0 1 0], 'linewidth',1.05);
d=plot(TOCd,HId,'*','Color',[0 0 1], 'linewidth',1.05);
e=plot(TOCe,HIe,'*','Color',[1 0 1], 'linewidth',1.05);
f=plot(TOCf,HIf,'*','Color',[0 1 1], 'linewidth',1.05);
g=plot(TOCg,HIg,'*','Color',[0 0.5 1], 'linewidth',1.05);

text(0.2,5000,'Contaminated','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(0.225,4000,'or stained','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(18,90,'Gas source','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(4.5,15,'Adequate gas','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(0.12,70,'Very','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(0.12,55,'poor','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(0.12,40,'source','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);

z=text(1.1,800,'Excellent oil source','Fontname',
'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
set(z,'rotation',29)

x=text(1.5,350,'Good oil source','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0
0 0]);
set(x,'rotation',29)

y=text(2,250,'Fair oil source','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
set(y,'rotation',29)

v=text(2.5,165,'gas and/or oil source','Fontname',
'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
set(v,'rotation',29)

title('HI - TOC by Age','FontName','Arial','FontWeight','bold','FontSize',25);
ylabel('Hydrogen Index (HI) (mg HC/g TOC)', 'Fontname',
'arial','FontWeight','bold','FontSize',24)
xlabel('TOC (wt %)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)

legend([f e g d c b a], 'Pliocene', 'Miocene', 'Neogene', ...
    'Oligocene', 'Cretaceous', 'Jurassic', 'Triassic');



%% PI_TMAX
TPIL1=[432.5 0;432.5 0.9];
TPIL2=[460 0;460 0.9];
TPIL3=[0 0.08;460 0.08];

figure
hold on

PIa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'N2:N15');
TMAXa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'G2:G15');
PIb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'N16:N159');
TMAXb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'G16:G159');
PIc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'N172:N185');
TMAXc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'G172:G185');
PId = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'N188:N197');
```

```
TMAXd = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'G188:G197');
PIe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'N198:N283');
TMAXe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'G198:G283');
PIf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'N289:N324');
TMAXf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'G289:G324');
PIg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'N325:N334');
TMAXg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'G325:G334');

title('PI - Tmax by Age','FontName','Arial','FontWeight','bold','FontSize',25);
plot(TPIL1(:,1),TPIL1(:,2),'k','LineWidth',2)
plot(TPIL2(:,1),TPIL2(:,2),'k','LineWidth',2)
plot(TPIL3(:,1),TPIL3(:,2),'k','LineWidth',2)

text(410,0.8,'Stains or shows','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(440,0.8,'Oil Window','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(465,0.8,'Wet gas zone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);

ylim([0 0.9])
xlim([400 480])

set(gca,'box', 'on','Fontname', 'arial','FontSize', 20)

a=plot(TMAXa,PIa,'*','Color',[0 0 0], 'linewidth',1.05);
hold on
b=plot(TMAXb,PIb,'*','Color',[1 0 0], 'linewidth',1.05);
c=plot(TMAXc,PIc,'*','Color',[0 1 0], 'linewidth',1.05);
d=plot(TMAXd,PId,'*','Color',[0 0 1], 'linewidth',1.05);
e=plot(TMAXe,PIe,'*','Color',[1 0 1], 'linewidth',1.05);
f=plot(TMAXf,PIf,'*','Color',[0 1 1], 'linewidth',1.05);
g=plot(TMAXg,PIg,'*','Color',[0 0.5 1], 'linewidth',1.05);

ylabel('Production Index (PI)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)
xlabel('T_m_a_x (C)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)

legend([f e g d c b a], 'Pliocene', 'Miocene', 'Neogene', ...
    'Oligocene', 'Cretaceous', 'Jurassic', 'Triassic');




%% S1S2_TOC
HLINE1=[0.1 2;100 2];
HLINE2=[0.1 6;100 6];
HLINE3=[0.1 20;100 20];
VLINE1=[0.5 0.01;0.5 1000];
VLINE2=[1 0.01;1 1000];
VLINE3=[2 0.01;2 1000];

S1a = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'H2:H15');
S2a = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I2:I15');
TOCa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K2:K15');
S1b = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'H16:H165');
S2b = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I16:I165');
TOCb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K16:K165');
S1c = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'H172:H186');
S2c = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I172:I186');
TOCc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K172:K186');
S1d = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'H188:H197');
S2d = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I188:I197');
TOCd = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K188:K197');
S1e = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'H198:H287');
S2e = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I198:I287');
TOCe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K198:K287');
S1f = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'H289:H324');
S2f = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I289:I324');
TOCf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K289:K324');
S1g = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'H325:H342');
S2g = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I325:I342');
```

```
TOCg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K325:K342');

figure
hold on
title('S1+S2 - TOC by Age','FontName','Arial','FontWeight','bold','FontSize',25);
plot(HLINE1(:,1),HLINE1(:,2),'k','LineWidth', 2)
plot(HLINE2(:,1),HLINE2(:,2),'k','LineWidth', 2)
plot(HLINE3(:,1),HLINE3(:,2),'k','LineWidth', 2)
plot(VLINE1(:,1),VLINE1(:,2),'k','LineWidth', 2)
plot(VLINE2(:,1),VLINE2(:,2),'k','LineWidth', 2)
plot(VLINE3(:,1),VLINE3(:,2),'k','LineWidth', 2)

set(gca,'XScale','log', 'box', 'on','Fontname', 'arial','FontSize', 20)
set(gca,'Yscale','log', 'box', 'on','Fontname', 'arial','FontSize', 20)

a=plot(TOCa,S2a+S1a,'*','Color',[0 0 0], 'linewidth',1.05);
hold on
b=plot(TOCb,S2b+S1b,'*','Color',[1 0 0], 'linewidth',1.05);
c=plot(TOCc,S2c+S1c,'*','Color',[0 1 0], 'linewidth',1.05);
d=plot(TOCd,S2d+S1d,'*','Color',[0 0 1], 'linewidth',1.05);
e=plot(TOCe,S2e+S1e,'*','Color',[1 0 1], 'linewidth',1.05);
f=plot(TOCf,S2f+S1f,'*','Color',[0 1 1], 'linewidth',1.05);
g=plot(TOCg,S2g+S1g,'*','Color',[0 0.5 1], 'linewidth',1.05);

ylim([0 1000])
xlim([0.1 100])

text(0.15,0.2,'Poor','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(0.55,0.2,'Fair','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(1.05,0.2,'Good','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(5,0.2,'Excellent','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(0.15,100,'Excellent','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(0.15,9,'Good','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(0.15,3,'Fair','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);

ylabel('S1+S2 (mg HC/g rock)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)
xlabel('TOC (wt %)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)

legend([f e g d c b a], 'Pliocene', 'Miocene', 'Neogene', ...
    'Oligocene', 'Cretaceous', 'Jurassic', 'Triassic');



%% S1_TOC
LINE=[0.1 0.31;51 41];

figure
hold on
title('S1 - TOC by Age','FontName','Arial','FontWeight','bold','FontSize',25);
plot(LINE(:,1),LINE(:,2),'k','LineWidth',2)

S1a = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'H2:H15');
TOCa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K2:K15');
S1b = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'H16:H165');
TOCb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K16:K165');
S1c = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'H172:H186');
TOCc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K172:K186');
S1d = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'H188:H197');
TOCd = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K188:K197');
S1e = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'H198:H287');
TOCe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K198:K287');
S1f = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'H289:H324');
TOCf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K289:K324');
S1g = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'H325:H342');
TOCg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K325:K342');

a = plot(TOCa,S1a,'*','Color',[0 0 0], 'linewidth',1.05);
hold on
b = plot(TOCb,S1b,'*','Color',[1 0 0], 'linewidth',1.05);
c = plot(TOCc,S1c,'*','Color',[0 1 0], 'linewidth',1.05);
```

```
d = plot(TOCd,S1d,'*','Color',[0 0 1], 'linewidth',1.05);
e = plot(TOCe,S1e,'*','Color',[1 0 1], 'linewidth',1.05);
f = plot(TOCf,S1f,'*','Color',[0 1 1], 'linewidth',1.05);
g = plot(TOCg,S1g,'*','Color',[0 0.5 1], 'linewidth',1.05);

ylim([0.01 10.00])
xlim([0.10 100.00])

text(0.15,8,'Non-indigenous','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(0.15,6,'hydrocarbons','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(5,0.2,'Indigenous','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(5,0.15,'hydrocarbons','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);

ylabel('S1 (mg HC/g rock)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)
xlabel('TOC (wt%)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)

set(gca,'XScale','log','box', 'on','Fontname', 'arial','FontSize', 20)
set(gca,'Yscale','log','box', 'on','Fontname', 'arial','FontSize', 20)

legend([f e g d c b a], 'Pliocene', 'Miocene', 'Neogene', ...
    'Oligocene', 'Cretaceous', 'Jurassic', 'Triassic');




%% S2_TOC
LineI=[0 0;11.996 6.3982];
LineII=[0 0;12.001 23.47];
LineIII=[0 0;11.999 34.793];
LineIV=[0 0;7.4634 50.016];
figure
hold on

S2a = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I2:I15');
TOCa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K2:K15');
S2b = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I16:I165');
TOCb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K16:K165');
S2c = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I172:I186');
TOCc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K172:K186');
S2d = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I188:I197');
TOCd = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K188:K197');
S2e = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I198:I287');
TOCe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K198:K287');
S2f = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I289:I324');
TOCf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K289:K324');
S2g = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I325:I342');
TOCg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K325:K342');

plot(LineI(:,1),LineI(:,2),'k','LineWidth',2,'LineStyle',':')
plot(LineII(:,1),LineII(:,2),'k','LineWidth',2,'LineStyle',':')
plot(LineIII(:,1),LineIII(:,2),'k','LineWidth',2,'LineStyle',':')
plot(LineIV(:,1),LineIV(:,2),'k','LineWidth',2,'LineStyle',':')

a=plot(TOCa,S2a,'*','Color',[0 0 0], 'linewidth',1.05);
hold on
b=plot(TOCb,S2b,'*','Color',[1 0 0], 'linewidth',1.05);
c=plot(TOCc,S2c,'*','Color',[0 1 0], 'linewidth',1.05);
d=plot(TOCd,S2d,'*','Color',[0 0 1], 'linewidth',1.05);
e=plot(TOCe,S2e,'*','Color',[1 0 1], 'linewidth',1.05);
f=plot(TOCf,S2f,'*','Color',[0 1 1], 'linewidth',1.05);
g=plot(TOCg,S2g,'*','Color',[0 0.5 1], 'linewidth',1.05);

set(gca, 'box', 'on','Fontname', 'arial','FontSize', 20)

ylim([0 50])
xlim([0 12])
```

```
text(3,47,'Type I Oil Prone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(3,45,'(Usually Lacustrine)','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0
0 0]);
text(8.5,47,'Type II Oil Prone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0
0 0]);
text(8.5,45,'(Usually Marine)','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(10,26,'Type II / III','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(10,24,'Oil/Gas Prone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(9.6,14,'Type III Gas Prone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0
0 0]);
text(10,3.5,'Dry Gas Prone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);

title('S2 - TOC by Age','FontName','Arial','FontWeight','bold','FontSize',25);
xlabel('TOC (wt %)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)
ylabel('Hydrocarbon Potential (S2, mg HC/g rock)', 'Fontname',
'arial','FontWeight','bold','FontSize',24)

legend([f e g d c b a], 'Pliocene', 'Miocene', 'Neogene', ...
    'Oligocene', 'Cretaceous', 'Jurassic', 'Triassic');


%% Van Krevelen
TypeI=dlmread('./Van_Krevelen/TypeI.txt',';');
TypeII=dlmread('./Van_Krevelen/TypeII.txt',';');
TypeIII=dlmread('./Van_Krevelen/TypeIII.txt',';');
TypeIV=dlmread('./Van_Krevelen/TypeIV.txt',';');

figure
hold on

plot(TypeI(:,1),TypeI(:,2),'k','LineWidth',3,'Linesmoothing', 'on','LineStyle','--')
text(40,848,'Type I','Fontname', 'arial', 'FontWeight','bold','FontSize',20);
plot(TypeII(:,1),TypeII(:,2),'k','LineWidth',3,'Linesmoothing', 'on','LineStyle','--')
text(65,616,'Type II','Fontname', 'arial','FontWeight','bold','FontSize',18);
plot(TypeIII(:,1),TypeIII(:,2),'k','LineWidth',3,'Linesmoothing', 'on','LineStyle','--')
text(170,150,'Type III','Fontname', 'arial','FontWeight','bold','FontSize',18);
plot(TypeIV(:,1),TypeIV(:,2),'k','LineWidth',3,'Linesmoothing', 'on','LineStyle','--')
text(175,34,'Type IV','Fontname', 'arial','FontWeight','bold','FontSize',18);

S2a = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I2:I15');
S3a = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'J2:J15');
TOCa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K2:K15');
S2b = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I16:I165');
S3b = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'J16:J165');
TOCb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K16:K165');
S2c = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I172:I186');
S3c = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'J172:J186');
TOCc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K172:K186');
S2d = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I188:I197');
S3d = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'J188:J197');
TOCd = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K188:K197');
S2e = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I198:I287');
S3e = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'J198:J287');
TOCe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K198:K287');
S2f = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I289:I324');
S3f = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'J289:J324');
TOCf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K289:K324');
S2g = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'I325:I342');
S3g = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'J325:J342');
TOCg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',2,'K325:K342');

a = plot(100*S3a./TOCa, 100*S2a./TOCa,'*', 'Color',[0 0 0], 'linewidth',1.05);
b = plot(100*S3b./TOCb, 100*S2b./TOCb,'*', 'Color',[1 0 0], 'linewidth',1.05);
c = plot(100*S3c./TOCc, 100*S2c./TOCc,'*', 'Color',[0 1 0], 'linewidth',1.05);
d = plot(100*S3d./TOCd, 100*S2d./TOCd,'*', 'Color',[0 0 1], 'linewidth',1.05);
e = plot(100*S3e./TOCe, 100*S2e./TOCe,'*', 'Color',[1 0 1], 'linewidth',1.05);
```

```
f = plot(100*S3f./TOCf, 100*S2f./TOCf,'*', 'Color',[0 1 1], 'linewidth',1.05);
g = plot(100*S3g./TOCg, 100*S2g./TOCg,'*', 'Color',[0 0.5 1], 'linewidth',1.05);

ylim([0 900])
xlim([0 200])
set(gca, 'box', 'on' , 'linewidth', 2,  'Fontname', 'arial','FontSize', 20)

title('van Krevelen Diagram by Age','FontName','Arial','FontWeight','bold','FontSize',25);
xlabel('Oxygen Index (OI, mg CO_2/g TOC)', 'FontName','Arial','FontWeight','bold','FontSize',25)
ylabel('Hydrogen Index (HI, mg HC/g TOC)', 'FontName','Arial','FontWeight','bold','FontSize',25)

legend([f e g d c b a], 'Pliocene', 'Miocene', 'Neogene', ...
    'Oligocene', 'Cretaceous', 'Jurassic', 'Triassic');
```

By Formation:

```
%% HI_TMAX

Ro05=dlmread('./Type_Maturity/KerMat05Ro.txt',';');
Ro135=dlmread('./Type_Maturity/KerMat135Ro.txt',';');
LimL=dlmread('./Type_Maturity/KerMatLeftLimit.txt',';');
LimR=dlmread('./Type_Maturity/KerMatRightLimit.txt',';');
T_MI=dlmread('./Type_Maturity/KerMatTypeI.txt',';');
T_MII=dlmread('./Type_Maturity/KerMatTypeII.txt',';');
T_MIII=dlmread('./Type_Maturity/KerMatTypeIII.txt',';');

HIa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L2:L15');
TMAXa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G2:G15');
HIb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L17:L51');
TMAXb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G17:G51');
HIc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L52:L123');
TMAXc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G52:G123');
HId = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L125:L126');
TMAXd = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G125:G126');
HIe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L128:L147');
TMAXe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G128:G147');
HIf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L154:L167');
TMAXf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G154:G167');
HIg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L168:L176');
TMAXg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G168:G176');
HIh = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L177:L197');
TMAXh = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G177:G197');
HIi = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L203:L208');
TMAXi = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G203:G208');
HIj = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L209:L222');
TMAXj = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G209:G222');
HIk = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L223:L224');
TMAXk = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G223:G224');
HIl = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L225:L308');
TMAXl = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G225:G308');
HIm = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L309:L318');
TMAXm = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G309:G318');
HIn = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L327:L331');
TMAXn = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G327:G331');
HIo = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L333:L338');
TMAXo = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G333:G338');

figure
hold on

title('HI - Tmax by Formation','FontName','Arial','FontWeight','bold','FontSize',25);
plot(Ro05(:,1),Ro05(:,2),'k','LineWidth',3,'LineSmoothing','on','LineStyle','--')
plot(Ro135(:,1),Ro135(:,2),'k','LineWidth',3,'LineSmoothing','on','LineStyle','--')
plot(LimL(:,1),LimL(:,2),'k','LineWidth',3,'LineStyle',':')
plot(LimR(:,1),LimR(:,2),'k','LineWidth',3,'LineStyle',':')
plot(T_MI(:,1),T_MI(:,2),'k','LineWidth',3,'LineSmoothing','on')
```

```
plot(T_MII(:,1),T_MII(:,2),'k','LineWidth',3,'LineSmoothing','on')
plot(T_MIII(:,1),T_MIII(:,2),'k','LineWidth',3,'LineSmoothing','on')


a=plot(TMAXa,HIa,'*','Color',[0 0 0], 'linewidth',1.05);
hold on
b=plot(TMAXb,HIb,'*','Color',[1 0 0], 'linewidth',1.05);
c=plot(TMAXc,HIc,'*','Color',[0 1 0], 'linewidth',1.05);
d=plot(TMAXd,HId,'*','Color',[0 0 1], 'linewidth',1.05);
e=plot(TMAXe,HIe,'*','Color',[1 0 1], 'linewidth',1.05);
f=plot(TMAXf,HIf,'*','Color',[0 1 1], 'linewidth',1.05);
g=plot(TMAXg,HIg,'*','Color',[0 0.5 1], 'linewidth',1.05);
h=plot(TMAXh,HIh,'*','Color',[0.5 0 1], 'linewidth',1.05);
i=plot(TMAXi,HIi,'*','Color',[1 0.5 0], 'linewidth',1.05);
j=plot(TMAXj,HIj,'*','Color',[0.5 0 0], 'linewidth',1.05);
k=plot(TMAXk,HIk,'*','Color',[1 0.8 0.2], 'linewidth',1.05);
l=plot(TMAXl,HIl,'*','Color',[1 0.3 0.1], 'linewidth',1.05);
m=plot(TMAXm,HIm,'*','Color',[0.4 0 0.8], 'linewidth',1.05);
n=plot(TMAXn,HIn,'*','Color',[0 0.3 0.7], 'linewidth',1.05);
o=plot(TMAXo,HIo,'*','Color',[0 0.6 0.5], 'linewidth',1.05);

set(gca, 'box', 'on', 'linewidth', 2,'Fontname', 'arial','FontSize', 20)
ylim([0 1000])
xlim([350 550])

text(355,140,'Type III','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(355,110,'Oil/Gas Prone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(375,650,'Type II','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(375,620,'Oil Prone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(375,590,'(Usually Marine)','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0
0 0]);
text(385,910,'Type I','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(385,880,'Oil Prone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(385,850,'Usually Lacustrine','Fontname',
'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(400,970,'Immature','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(445,970,'Mature','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(440,940,'(Oil Window)','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(485,970,'Postmature','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(460,730,'0.5% Ro','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(475,180,'1.35% Ro','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(475,470,'Condensate-Wet Gas Window','Fontname',
'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(485,130,'Dry Gas Window','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);

xlabel('T_m_a_x (C^o)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)
ylabel('Hydrogen Index (HI, mg HC/g TOC)','Fontname', 'arial','FontWeight','bold','FontSize',24)

legend([a b c d e f g h i j k l m n o], 'Vigla Shales', 'Posidonia Beds', 'Undifferentiated
Posidonia Beds', 'Upper Posidonia Beds', ...
    'Lower Posidonia Beds', 'Triassic Breccias and Shale Fragments', 'Ammonitico Rosso Base',
'Marly Limestones', ...
    'Deltaic', 'Mudstone Slope', 'Channel Fill', 'Silt, Clay, and Sand', 'Sediment and Alluvial
Deposits', 'Sapropel', 'Pantokrator Limestones');


%% HI_TOC
L1=[0.3 10;0.3 90];
L2=[0.64 30;100 30];
L3=[0.1 90;1.05 90];
L4=[0.17 180;1.06 180];
L5=[0.38 395;1.065 395];
L6=[0.63 30;100 3800];
L7=[1.05 90;100 6000];
L8=[1.06 180;71 10000];
L9=[1.065 395;34 10000];
L10=[0.1 105;9.4 10000];
```

```
figure
hold on

HIa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L2:L15');
TOCa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K2:K15');
HIb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L17:L51');
TOCb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K17:K51');
HIc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L52:L123');
TOCc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K52:K123');
HId = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L125:L126');
TOCd = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K125:K126');
HIe = [xlsread('G:\Masters Thesis stuff\Western Greece
Database.xlsx',1,'L128:L147');36.73;24.99];
TOCe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K128:K149');
HIf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L154:L167');
TOCf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K154:K167');
HIg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L168:L176');
TOCg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K168:K176');
HIh = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L177:L197');
TOCh = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K177:K197');
HIi = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L199:L202');
TOCi = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K199:K202');
HIj = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L203:L208');
TOCj = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K203:K208');
HIk = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L209:L222');
TOCk = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K209:K222');
HIl = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L223:L224');
TOCl = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K223:K224');
HIm = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L225:L308');
TOCm = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K225:K308');
HIn = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L309:L326');
TOCn = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K309:K326');
HIo = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L327:L331');
TOCo = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K327:K331');
HIp = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L332:L332');
TOCp = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K332:K332');
HIq = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'L333:L342');
TOCq = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K333:K342');

plot(L1(:,1),L1(:,2),'k','LineWidth',1.5)
plot(L2(:,1),L2(:,2),'k','LineWidth',1.5)
plot(L3(:,1),L3(:,2),'k','LineWidth',1.5)
plot(L4(:,1),L4(:,2),'k','LineWidth',1.5)
plot(L5(:,1),L5(:,2),'k','LineWidth',1.5)
plot(L6(:,1),L6(:,2),'k','LineWidth',1.5)
plot(L7(:,1),L7(:,2),'k','LineWidth',1.5)
plot(L8(:,1),L8(:,2),'k','LineWidth',1.5)
plot(L9(:,1),L9(:,2),'k','LineWidth',1.5)
plot(L10(:,1),L10(:,2),'k','LineWidth',1.5)

set(gca,'XScale','log','box', 'on', 'Fontname', 'arial','FontSize', 20)
set(gca,'YScale','log','box', 'on','Fontname', 'arial', 'FontSize', 20)

axis on
ylim([10 10000])
xlim([0.1 100])

a=plot(TOCa,HIa,'*','Color',[0 0 0], 'linewidth',1.05);
hold on
b=plot(TOCb,HIb,'*','Color',[1 0 0], 'linewidth',1.05);
c=plot(TOCc,HIc,'*','Color',[0 1 0], 'linewidth',1.05);
d=plot(TOCd,HId,'*','Color',[0 0 1], 'linewidth',1.05);
e=plot(TOCe,HIe,'*','Color',[1 0 1], 'linewidth',1.05);
f=plot(TOCf,HIf,'*','Color',[0 1 1], 'linewidth',1.05);
g=plot(TOCg,HIg,'*','Color',[0 0.5 1], 'linewidth',1.05);
h=plot(TOCh,HIh,'*','Color',[0.5 0 1], 'linewidth',1.05);
i=plot(TOCi,HIi,'*','Color',[1 0.5 0], 'linewidth',1.05);
j=plot(TOCj,HIj,'*','Color',[0.5 0 0], 'linewidth',1.05);
k=plot(TOCk,HIk,'*','Color',[1 0.8 0.2], 'linewidth',1.05);
l=plot(TOCl,HIl,'*','Color',[1 0.3 0.1], 'linewidth',1.05);
m=plot(TOCm,HIm,'*','Color',[0.4 0 0.8], 'linewidth',1.05);
```

```
n=plot(TOCn,HIn,'*','Color',[0 0.3 0.7], 'linewidth',1.05);
o=plot(TOCo,HIo,'*','Color',[0 0.6 0.5], 'linewidth',1.05);
p=plot(TOCp,HIp,'*','Color',[0.2 0.6 0], 'linewidth',1.05);
q=plot(TOCq,HIq,'*','Color',[0.2 0 0.4], 'linewidth',1.05);

text(0.2,5000,'Contaminated','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(0.225,4000,'or stained','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(18,90,'Gas source','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(4.5,15,'Adequate gas','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(0.12,70,'Very','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(0.12,55,'poor','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(0.12,40,'source','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);

z=text(1.1,800,'Excellent oil source','Fontname',
'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
set(z,'rotation',29)

x=text(1.5,350,'Good oil source','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0
0 0]);
set(x,'rotation',29)

y=text(2,250,'Fair oil source','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
set(y,'rotation',29)

v=text(2.5,165,'gas and/or oil source','Fontname',
'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
set(v,'rotation',29)

title('HI - TOC by Formation','FontName','Arial','FontWeight','bold','FontSize',25);
ylabel('Hydrogen Index (HI) (mg HC/g TOC)', 'Fontname',
'arial','FontWeight','bold','FontSize',24)
xlabel('TOC (wt %)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)

legend([a b c d e f g h i j k l m n o p q], 'Vigla Shales', 'Posidonia Beds', 'Undifferentiated
Posidonia Beds', 'Upper Posidonia Beds', ...
    'Lower Posidonia Beds', 'Triassic Breccias and Shale Fragments', 'Ammonitico Rosso Base',
'Marly Limestones', 'Turbidite Deposits',...
    'Deltaic', 'Mudstone Slope', 'Channel Fill', 'Silt, Clay, and Sand', 'Sediment and Alluvial
Deposits', 'Sapropel', 'Pantokrator Limestones');



%% PI_TMAX
TPIL1=[432.5 0;432.5 0.9];
TPIL2=[460 0;460 0.9];
TPIL3=[0 0.08;460 0.08];

figure
hold on

PIa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'N2:N15');
TMAXa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G2:G15');
PIb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'N17:N51');
TMAXb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G17:G51');
PIc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'N52:N123');
TMAXc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G52:G123');
PId = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'N125:N126');
TMAXd = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G125:G126');
PIe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'N128:N147');
TMAXe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G128:G147');
PIf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'N154:N167');
TMAXf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G154:G167');
PIg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'N168:N176');
TMAXg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G168:G176');
PIh = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'N177:N197');
TMAXh = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G177:G197');
```

```
PIi = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'N203:N208');
TMAXi = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G203:G208');
PIj = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'N209:N222');
TMAXj = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G209:G222');
PIk = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'N223:N224');
TMAXk = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G223:G224');
PIl = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'N225:N308');
TMAXl = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G225:G308');
PIm = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'N309:N318');
TMAXm = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G309:G318');
PIn = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'N327:N331');
TMAXn = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G327:G331');
PIo = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'N333:N338');
TMAXo = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'G333:G338');

title('PI - Tmax by Formation','FontName','Arial','FontWeight','bold','FontSize',25);
plot(TPIL1(:,1),TPIL1(:,2),'k','LineWidth',2)
plot(TPIL2(:,1),TPIL2(:,2),'k','LineWidth',2)
plot(TPIL3(:,1),TPIL3(:,2),'k','LineWidth',2)

text(410,0.8,'Stains or shows','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(440,0.8,'Oil Window','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(465,0.8,'Wet gas zone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);

ylim([0 0.9])
xlim([400 480])

set(gca,'box', 'on','Fontname', 'arial','FontSize', 20)

a=plot(TMAXa,PIa,'*','Color',[0 0 0], 'linewidth',1.05);
hold on
b=plot(TMAXb,PIb,'*','Color',[1 0 0], 'linewidth',1.05);
c=plot(TMAXc,PIc,'*','Color',[0 1 0], 'linewidth',1.05);
d=plot(TMAXd,PId,'*','Color',[0 0 1], 'linewidth',1.05);
e=plot(TMAXe,PIe,'*','Color',[1 0 1], 'linewidth',1.05);
f=plot(TMAXf,PIf,'*','Color',[0 1 1], 'linewidth',1.05);
g=plot(TMAXg,PIg,'*','Color',[0 0.5 1], 'linewidth',1.05);
h=plot(TMAXh,PIh,'*','Color',[0.5 0 1], 'linewidth',1.05);
i=plot(TMAXi,PIi,'*','Color',[1 0.5 1], 'linewidth',1.05);
j=plot(TMAXj,PIj,'*','Color',[0.5 0 0], 'linewidth',1.05);
k=plot(TMAXk,PIk,'*','Color',[1 0.8 0.2], 'linewidth',1.05);
l=plot(TMAXl,PIl,'*','Color',[1 0.3 0.1], 'linewidth',1.05);
m=plot(TMAXm,PIm,'*','Color',[0.4 0 0.8], 'linewidth',1.05);
n=plot(TMAXn,PIn,'*','Color',[0 0.3 0.7], 'linewidth',1.05);
o=plot(TMAXo,PIo,'*','Color',[0 0.6 0.5], 'linewidth',1.05);

ylabel('Production Index (PI)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)
xlabel('T_m_a_x (C)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)

legend([a b c d e f g h i j k l m n o], 'Vigla Shales', 'Posidonia Beds', 'Undifferentiated
Posidonia Beds', 'Upper Posidonia Beds', ...
    'Lower Posidonia Beds', 'Triassic Breccias and Shale Fragments', 'Ammonitico Rosso Base',
'Marly Limestones', ...
    'Deltaic', 'Mudstone Slope', 'Channel Fill', 'Silt, Clay, and Sand', 'Sediment and Alluvial
Deposits', 'Sapropel', 'Pantokrator Limestones');


%% S1S2_TOC
HLINE1=[0.1 2;100 2];
HLINE2=[0.1 6;100 6];
HLINE3=[0.1 20;100 20];
VLINE1=[0.5 0.01;0.5 1000];
VLINE2=[1 0.01;1 1000];
VLINE3=[2 0.01;2 1000];

S1a = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H2:H15');
S2a = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I2:I15');
TOCa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K2:K15');
S1b = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H17:H51');
```

```
S2b = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I17:I51');
TOCb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K17:K51');
S1c = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H52:H123');
S2c = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I52:I123');
TOCc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K52:K123');
S1d = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H125:H126');
S2d = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I125:I126');
TOCd = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K125:K126');
S1e = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H128:H149');
S2e = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I128:I149');
TOCe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K128:K149');
S1f = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H154:H167');
S2f = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I154:I167');
TOCf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K154:K167');
S1g = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H168:H176');
S2g = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I168:I176');
TOCg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K168:K176');
S1h = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H177:H197');
S2h = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I177:I197');
TOCh = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K177:K197');
S1i = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H199:H202');
S2i = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I199:I202');
TOCi = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K199:K202');
S1j = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H203:H208');
S2j = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I203:I208');
TOCj = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K203:K208');
S1k = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H209:H222');
S2k = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I209:I222');
TOCk = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K209:K222');
S1l = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H223:H224');
S2l = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I223:I224');
TOCl = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K223:K224');
S1m = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H225:H308');
S2m = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I225:I308');
TOCm = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K225:K308');
S1n = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H309:H326');
S2n = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I309:I326');
TOCn = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K309:K326');
S1o = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H327:H331');
S2o = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I327:I331');
TOCo = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K327:K331');
S1p = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H332:H332');
S2p = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I332:I332');
TOCp = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K332:K332');
S1q = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H333:H342');
S2q = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I333:I342');
TOCq = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K333:K342');

figure
hold on
title('S1+S2 - TOC by Formation','FontName','Arial','FontWeight','bold','FontSize',25);
plot(HLINE1(:,1),HLINE1(:,2),'k','LineWidth', 2)
plot(HLINE2(:,1),HLINE2(:,2),'k','LineWidth', 2)
plot(HLINE3(:,1),HLINE3(:,2),'k','LineWidth', 2)
plot(VLINE1(:,1),VLINE1(:,2),'k','LineWidth', 2)
plot(VLINE2(:,1),VLINE2(:,2),'k','LineWidth', 2)
plot(VLINE3(:,1),VLINE3(:,2),'k','LineWidth', 2)

set(gca,'XScale','log', 'box', 'on','Fontname', 'arial','FontSize', 20)
set(gca,'Yscale','log', 'box', 'on','Fontname', 'arial','FontSize', 20)

a=plot(TOCa,S2a+S1a,'*','Color',[0 0 0], 'linewidth',1.05);
hold on
b=plot(TOCb,S2b+S1b,'*','Color',[1 0 0], 'linewidth',1.05);
c=plot(TOCc,S2c+S1c,'*','Color',[0 1 0], 'linewidth',1.05);
d=plot(TOCd,S2d+S1d,'*','Color',[0 0 1], 'linewidth',1.05);
e=plot(TOCe,S2e+S1e,'*','Color',[1 0 1], 'linewidth',1.05);
f=plot(TOCf,S2f+S1f,'*','Color',[0 1 1], 'linewidth',1.05);
g=plot(TOCg,S2g+S1g,'*','Color',[0 0.5 1], 'linewidth',1.05);
h=plot(TOCh,S2h+S1h,'*','Color',[0.5 0 1], 'linewidth',1.05);
i=plot(TOCi,S2i+S1i,'*','Color',[1 0.5 0], 'linewidth',1.05);
```

```
j=plot(TOCj,S2j+S1j,'*','Color',[0.5 0 0], 'linewidth',1.05);
k=plot(TOCk,S2k+S1k,'*','Color',[1 0.8 0.2], 'linewidth',1.05);
l=plot(TOCl,S2l+S1l,'*','Color',[1 0.3 0.1], 'linewidth',1.05);
m=plot(TOCm,S2m+S1m,'*','Color',[0.4 0 0.8], 'linewidth',1.05);
n=plot(TOCn,S2n+S1n,'*','Color',[0 0.3 0.7], 'linewidth',1.05);
o=plot(TOCo,S2o+S1o,'*','Color',[0 0.6 0.5], 'linewidth',1.05);
p=plot(TOCp,S2p+S1p,'*','Color',[0.2 0.6 0], 'linewidth',1.05);
q=plot(TOCq,S2q+S1q,'*','Color',[0.2 0 0.4], 'linewidth',1.05);

ylim([0 1000])
xlim([0.1 100])

text(0.15,0.2,'Poor','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(0.55,0.2,'Fair','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(1.05,0.2,'Good','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(5,0.2,'Excellent','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(0.15,100,'Excellent','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(0.15,9,'Good','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(0.15,3,'Fair','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);

ylabel('S1+S2 (mg HC/g rock)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)
xlabel('TOC (wt %)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)

legend([a b c d e f g h i j k l m n o p q], 'Vigla Shales', 'Posidonia Beds', 'Undifferentiated
Posidonia Beds', 'Upper Posidonia Beds', ...
    'Lower Posidonia Beds', 'Triassic Breccias and Shale Fragments', 'Ammonitico Rosso Base',
'Marly Limestones', 'Turbidite Deposits',...
    'Deltaic', 'Mudstone Slope', 'Channel Fill', 'Silt, Clay, and Sand', 'Sediment and Alluvial
Deposits', 'Sapropel', 'Pantokrator Limestones');



%% S1_TOC
LINE=[0.1 0.31;51 41];

figure
hold on
title('S1 - TOC by Formation','FontName','Arial','FontWeight','bold','FontSize',25);
plot(LINE(:,1),LINE(:,2),'k','LineWidth',2)

S1a = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H2:H15');
TOCa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K2:K15');
S1b = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H17:H51');
TOCb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K17:K51');
S1c = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H52:H123');
TOCc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K52:K123');
S1d = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H125:H126');
TOCd = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K125:K126');
S1e = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H128:H149');
TOCe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K128:K149');
S1f = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H154:H167');
TOCf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K154:K167');
S1g = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H168:H176');
TOCg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K168:K176');
S1h = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H177:H197');
TOCh = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K177:K197');
S1i = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H199:H202');
TOCi = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K199:K202');
S1j = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H203:H208');
TOCj = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K203:K208');
S1k = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H209:H222');
TOCk = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K209:K222');
S1l = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H223:H224');
TOCl = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K223:K224');
S1m = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H225:H308');
TOCm = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K225:K308');
S1n = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H309:H326');
TOCn = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K309:K326');
S1o = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H327:H331');
TOCo = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K327:K331');
```

```
S1p = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H332:H322');
TOCp = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K332:K322');
S1q = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'H333:H342');
TOCq = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K333:K342');

a = plot(TOCa,S1a,'*','Color',[0 0 0], 'linewidth',1.05);
hold on
b = plot(TOCb,S1b,'*','Color',[1 0 0], 'linewidth',1.05);
c = plot(TOCc,S1c,'*','Color',[0 1 0], 'linewidth',1.05);
d = plot(TOCd,S1d,'*','Color',[0 0 1], 'linewidth',1.05);
e = plot(TOCe,S1e,'*','Color',[1 0 1], 'linewidth',1.05);
f = plot(TOCf,S1f,'*','Color',[0 1 1], 'linewidth',1.05);
g = plot(TOCg,S1g,'*','Color',[0 0.5 1], 'linewidth',1.05);
h = plot(TOCh,S1h,'*','Color',[0.5 0 1], 'linewidth',1.05);
i = plot(TOCi,S1i,'*','Color',[1 0.5 0], 'linewidth',1.05);
j = plot(TOCj,S1j,'*','Color',[0.5 0 0], 'linewidth',1.05);
k = plot(TOCk,S1k,'*','Color',[1 0.8 0.2], 'linewidth',1.05);
l = plot(TOCl,S1l,'*','Color',[1 0.3 0.1], 'linewidth',1.05);
m = plot(TOCm,S1m,'*','Color',[0.4 0 0.8], 'linewidth',1.05);
n = plot(TOCn,S1n,'*','Color',[0 0.3 0.7], 'linewidth',1.05);
o = plot(TOCo,S1o,'*','Color',[0 0.6 0.5], 'linewidth',1.05);
p = plot(TOCp,S1p,'*','Color',[0.2 0.6 0], 'linewidth',1.05);
q = plot(TOCq,S1q,'*','Color',[0.2 0 0.4], 'linewidth',1.05);

ylim([0.01 10.00])
xlim([0.10 100.00])

text(0.15,8,'Non-indigenous','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(0.15,6,'hydrocarbons','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(5,0.2,'Indigenous','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0 0]);
text(5,0.15,'hydrocarbons','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);

ylabel('S1 (mg HC/g rock)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)
xlabel('TOC (wt%)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)

set(gca,'XScale','log','box', 'on','Fontname', 'arial','FontSize', 20)
set(gca,'Yscale','log','box', 'on','Fontname', 'arial','FontSize', 20)

legend([a b c d e f g h i j k l m n o p q], 'Vigla Shales', 'Posidonia Beds', 'Undifferentiated
Posidonia Beds', 'Upper Posidonia Beds', ...
    'Lower Posidonia Beds', 'Triassic Breccias and Shale Fragments', 'Ammonitico Rosso Base',
'Marly Limestones', 'Turbidite Deposits',...
    'Deltaic', 'Mudstone Slope', 'Channel Fill', 'Silt, Clay, and Sand', 'Sediment and Alluvial
Deposits', 'Sapropel', 'Pantokrator Limestones');


%% S2_TOC
LineI=[0 0;11.996 6.3982];
LineII=[0 0;12.001 23.47];
LineIII=[0 0;11.999 34.793];
LineIV=[0 0;7.4634 50.016];
figure
hold on

S2a = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I2:I15');
TOCa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K2:K15');
S2b = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I17:I51');
TOCb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K17:K51');
S2c = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I52:I123');
TOCc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K52:K123');
S2d = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I125:I126');
TOCd = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K125:K126');
S2e = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I128:I149');
TOCe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K128:K149');
S2f = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I154:I167');
TOCf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K154:K167');
S2g = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I168:I176');
TOCg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K168:K176');
S2h = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I177:I197');
```

```
TOCh = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K177:K197');
S2i = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I199:I202');
TOCi = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K199:K202');
S2j = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I203:I208');
TOCj = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K203:K208');
S2k = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I209:I222');
TOCk = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K209:K222');
S2l = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I223:I224');
TOCl = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K223:K224');
S2m = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I225:I308');
TOCm = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K225:K308');
S2n = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I309:I326');
TOCn = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K309:K326');
S2o = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I327:I331');
TOCo = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K327:K331');
S2p = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I332:I332');
TOCp = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K332:K332');
S2q = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I333:I342');
TOCq = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K333:K342');

plot(LineI(:,1),LineI(:,2),'k','LineWidth',2,'LineStyle',':')
plot(LineII(:,1),LineII(:,2),'k','LineWidth',2,'LineStyle',':')
plot(LineIII(:,1),LineIII(:,2),'k','LineWidth',2,'LineStyle',':')
plot(LineIV(:,1),LineIV(:,2),'k','LineWidth',2,'LineStyle',':')

a=plot(TOCa,S2a,'*','Color',[0 0 0], 'linewidth',1.05);
hold on
b=plot(TOCb,S2b,'*','Color',[1 0 0], 'linewidth',1.05);
c=plot(TOCc,S2c,'*','Color',[0 1 0], 'linewidth',1.05);
d=plot(TOCd,S2d,'*','Color',[0 0 1], 'linewidth',1.05);
e=plot(TOCe,S2e,'*','Color',[1 0 1], 'linewidth',1.05);
f=plot(TOCf,S2f,'*','Color',[0 1 1], 'linewidth',1.05);
g=plot(TOCg,S2g,'*','Color',[0 0.5 1], 'linewidth',1.05);
h=plot(TOCh,S2h,'*','Color',[0.5 0 1], 'linewidth',1.05);
i=plot(TOCi,S2i,'*','Color',[1 0.5 0], 'linewidth',1.05);
j=plot(TOCj,S2j,'*','Color',[0.5 0 0], 'linewidth',1.05);
k=plot(TOCk,S2k,'*','Color',[1 0.8 0.2], 'linewidth',1.05);
l=plot(TOCl,S2l,'*','Color',[1 0.3 0.1], 'linewidth',1.05);
m=plot(TOCm,S2m,'*','Color',[0.4 0 0.8], 'linewidth',1.05);
n=plot(TOCn,S2n,'*','Color',[0 0.3 0.7], 'linewidth',1.05);
o=plot(TOCo,S2o,'*','Color',[0 0.6 0.5], 'linewidth',1.05);
p=plot(TOCp,S2p,'*','Color',[0.2 0.6 0], 'linewidth',1.05);
q=plot(TOCq,S2q,'*','Color',[0.2 0 0.4], 'linewidth',1.05);

set(gca, 'box', 'on','Fontname', 'arial','FontSize', 20)

ylim([0 50])
xlim([0 12])

text(3,47,'Type I Oil Prone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(3,45,'(Usually Lacustrine)','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0
0 0]);
text(8.5,47,'Type II Oil Prone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0
0 0]);
text(8.5,45,'(Usually Marine)','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(10,26,'Type II / III','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(10,24,'Oil/Gas Prone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);
text(9.6,14,'Type III Gas Prone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0
0 0]);
text(10,3.5,'Dry Gas Prone','Fontname', 'arial','FontWeight','bold','FontSize',20,'Color',[0 0
0]);

title('S2 - TOC by Formation','FontName','Arial','FontWeight','bold','FontSize',25);
xlabel('TOC (wt %)', 'Fontname', 'arial','FontWeight','bold','FontSize',24)
ylabel('Hydrocarbon Potential (S2, mg HC/g rock)', 'Fontname',
'arial','FontWeight','bold','FontSize',24)
```

```
legend([a b c d e f g h i j k l m n o p q], 'Vigla Shales', 'Posidonia Beds', 'Undifferentiated
Posidonia Beds', 'Upper Posidonia Beds', ...
    'Lower Posidonia Beds', 'Triassic Breccias and Shale Fragments', 'Ammonitico Rosso Base',
'Marly Limestones', 'Turbidite Deposits',...
    'Deltaic', 'Mudstone Slope', 'Channel Fill', 'Silt, Clay, and Sand', 'Sediment and Alluvial
Deposits', 'Sapropel', 'Pantokrator Limestones');



%% van Krevelen
TypeI=dlmread('./Van_Krevelen/TypeI.txt',';');
TypeII=dlmread('./Van_Krevelen/TypeII.txt',';');
TypeIII=dlmread('./Van_Krevelen/TypeIII.txt',';');
TypeIV=dlmread('./Van_Krevelen/TypeIV.txt',';');

figure
hold on

plot(TypeI(:,1),TypeI(:,2),'k','LineWidth',3,'Linesmoothing', 'on','LineStyle','--')
text(40,848,'Type I','Fontname', 'arial', 'FontWeight','bold','FontSize',20);
plot(TypeII(:,1),TypeII(:,2),'k','LineWidth',3,'Linesmoothing', 'on','LineStyle','--')
text(65,616,'Type II','Fontname', 'arial','FontWeight','bold','FontSize',18);
plot(TypeIII(:,1),TypeIII(:,2),'k','LineWidth',3,'Linesmoothing', 'on','LineStyle','--')
text(170,150,'Type III','Fontname', 'arial','FontWeight','bold','FontSize',18);
plot(TypeIV(:,1),TypeIV(:,2),'k','LineWidth',3,'Linesmoothing', 'on','LineStyle','--')
text(175,34,'Type IV','Fontname', 'arial','FontWeight','bold','FontSize',18);

S2a = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I2:I15');
S3a = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J2:J15');
TOCa = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K2:K15');
S2b = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I17:I51');
S3b = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J17:J51');
TOCb = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K17:K51');
S2c = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I52:I123');
S3c = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J52:J123');
TOCc = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K52:K123');
S2d = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I125:I126');
S3d = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J125:J126');
TOCd = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K125:K126');
S2e = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I128:I149');
S3e = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J128:J149');
TOCe = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K128:K149');
S2f = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I154:I167');
S3f = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J154:J167');
TOCf = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K154:K167');
S2g = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I168:I176');
S3g = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J168:J176');
TOCg = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K168:K176');
S2h = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I177:I197');
S3h = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J177:J197');
TOCh = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K177:K197');
S2i = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I199:I202');
S3i = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J199:J202');
TOCi = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K199:K202');
S2j = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I203:I208');
S3j = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J203:J208');
TOCj = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K203:K208');
S2k = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I209:I222');
S3k = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J209:J222');
TOCk = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K209:K222');
S2l = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I223:I224');
S3l = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J223:J224');
TOCl = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K223:K224');
S2m = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I225:I308');
S3m = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J225:J308');
TOCm = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K225:K308');
S2n = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I309:I326');
S3n = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J309:J326');
TOCn = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K309:K326');
S2o = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I327:I331');
```

```
S3o = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J327:J331');
TOCo = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K327:K331');
S2p = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I332:I332');
S3p = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J332:J332');
TOCp = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K332:K332');
S2q = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'I333:I342');
S3q = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'J333:J342');
TOCq = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',1,'K333:K342');

a = plot(100*S3a./TOCa, 100*S2a./TOCa,'*', 'Color',[0 0 0], 'linewidth',1.05);
b = plot(100*S3b./TOCb, 100*S2b./TOCb,'*', 'Color',[1 0 0], 'linewidth',1.05);
c = plot(100*S3c./TOCc, 100*S2c./TOCc,'*', 'Color',[0 1 0], 'linewidth',1.05);
d = plot(100*S3d./TOCd, 100*S2d./TOCd,'*', 'Color',[0 0 1], 'linewidth',1.05);
e = plot(100*S3e./TOCe, 100*S2e./TOCe,'*', 'Color',[1 0 1], 'linewidth',1.05);
f = plot(100*S3f./TOCf, 100*S2f./TOCf,'*', 'Color',[0 1 1], 'linewidth',1.05);
g = plot(100*S3g./TOCg, 100*S2g./TOCg,'*', 'Color',[0 0.5 1], 'linewidth',1.05);
h = plot(100*S3h./TOCh, 100*S2h./TOCh,'*', 'Color',[0.5 0 1], 'linewidth',1.05);
i = plot(100*S3i./TOCi, 100*S2i./TOCi,'*', 'Color',[1 0.5 0], 'linewidth',1.05);
j = plot(100*S3j./TOCj, 100*S2j./TOCj,'*', 'Color',[0.5 0 0], 'linewidth',1.05);
k = plot(100*S3k./TOCk, 100*S2k./TOCk,'*', 'Color',[1 0.8 0.2], 'linewidth',1.05);
l = plot(100*S3l./TOCl, 100*S2l./TOCl,'*', 'Color',[1 0.3 0.1], 'linewidth',1.05);
m = plot(100*S3m./TOCm, 100*S2m./TOCm,'*', 'Color',[0.4 0 0.8], 'linewidth',1.05);
n = plot(100*S3n./TOCn, 100*S2n./TOCn,'*', 'Color',[0 0.3 0.7], 'linewidth',1.05);
o = plot(100*S3o./TOCo, 100*S2o./TOCo,'*', 'Color',[0 0.6 0.5], 'linewidth',1.05);
p = plot(100*S3p./TOCp, 100*S2p./TOCp,'*', 'Color',[0.2 0.6 0], 'linewidth',1.05);
q = plot(100*S3q./TOCq, 100*S2q./TOCq,'*', 'Color',[0.2 0 0.4], 'linewidth',1.05);

ylim([0 900])
xlim([0 200])
set(gca, 'box', 'on' , 'linewidth', 2,  'Fontname', 'arial','FontSize', 20)

title('van Krevelen Diagram by Formation','FontName','Arial','FontWeight','bold','FontSize',25);
xlabel('Oxygen Index (OI, mg CO_2/g TOC)', 'FontName','Arial','FontWeight','bold','FontSize',25)
ylabel('Hydrogen Index (HI, mg HC/g TOC)', 'FontName','Arial','FontWeight','bold','FontSize',25)
legend([a b c d e f g h i j k l m n o p q], 'Vigla Shales', 'Posidonia Beds', 'Undifferentiated
Posidonia Beds', 'Upper Posidonia Beds', ...
    'Lower Posidonia Beds', 'Triassic Breccias and Shale Fragments', 'Ammonitico Rosso Base',
'Marly Limestones', 'Turbidite Deposits',...
    'Deltaic', 'Mudstone Slope', 'Channel Fill', 'Silt, Clay, and Sand', 'Sediment and Alluvial
Deposits', 'Sapropel', 'Pantokrator Limestones');
```

Alkanes code:

```
%% Alkanes by paper
[Data,Labels] = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx', 3,'A3:AT71');
[justData,someLabels] = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',
3,'F3:AT71');
Component_names = Labels(1, 7:28);

paper13 = Data(1:16,7:28);
paper12 = Data(17:33,7:28);
paper11 = Data(34:58,7:28);
paper10 = Data(59:68,7:28);

paper13_sum = Data(1:16, 46);
paper12_sum = Data(17:33, 46);
paper11_sum = Data(34:58, 46);
paper10_sum = Data(59:68, 46);

paper13_normal = paper13./paper13_sum;
paper12_normal = paper12./paper12_sum;
paper11_normal = paper11./paper11_sum;
paper10_normal = paper10./paper10_sum;

paper13_Sample_names = Labels(2:17,6);
paper12_Sample_names = Labels(18:34,6);
paper11_Sample_names = Labels(35:59,6);
paper10_Sample_names = Labels(60:69,6);

all_sample_names = Labels(2:69,6);

%% Bar-chart of Alkanes by paper
[nx,ny] = size(Component_names);
Tick = [1:ny];
axes1  =  axes('Parent', figure,'XTickLabel', paper13_Sample_names,'XTick', Tick);
box(axes1,'on');
hold(axes1,'all');
xlabel('Sample','FontSize',14);
ylabel('Value','FontSize',14);

bar(paper13_normal,'Parent', axes1);
title('Silt, Clay, and Sand','FontName','Arial','FontWeight','bold','FontSize',25);
h = legend(Component_names);
set(h, 'FontSize',14);
hold on;

axes2  =  axes('Parent', figure,'XTickLabel', paper12_Sample_names,'XTick', Tick);
box(axes2,'on');
hold(axes2,'all');
bar(paper12_normal,'Parent', axes2);
title('Sediment and Alluvial Deposits','FontName','Arial','FontWeight','bold','FontSize',25);
xlabel('Sample','FontSize',14);
ylabel('Value','FontSize',14);
h = legend(Component_names);
set(h, 'FontSize',14);

axes3  =  axes('Parent', figure,'XTickLabel', paper11_Sample_names,'XTick', Tick);
box(axes3,'on');
hold(axes3,'all');
bar(paper11_normal,'Parent', axes3);
title('Silt, Clay, Sand, and Sapropel','FontName','Arial','FontWeight','bold','FontSize',25);
xlabel('Sample','FontSize',14);
ylabel('Value','FontSize',14);
h = legend(Component_names);
set(h, 'FontSize',14);

axes4  =  axes('Parent', figure,'XTickLabel', paper10_Sample_names,'XTick', Tick);
box(axes4,'on');
hold(axes4,'all');
```

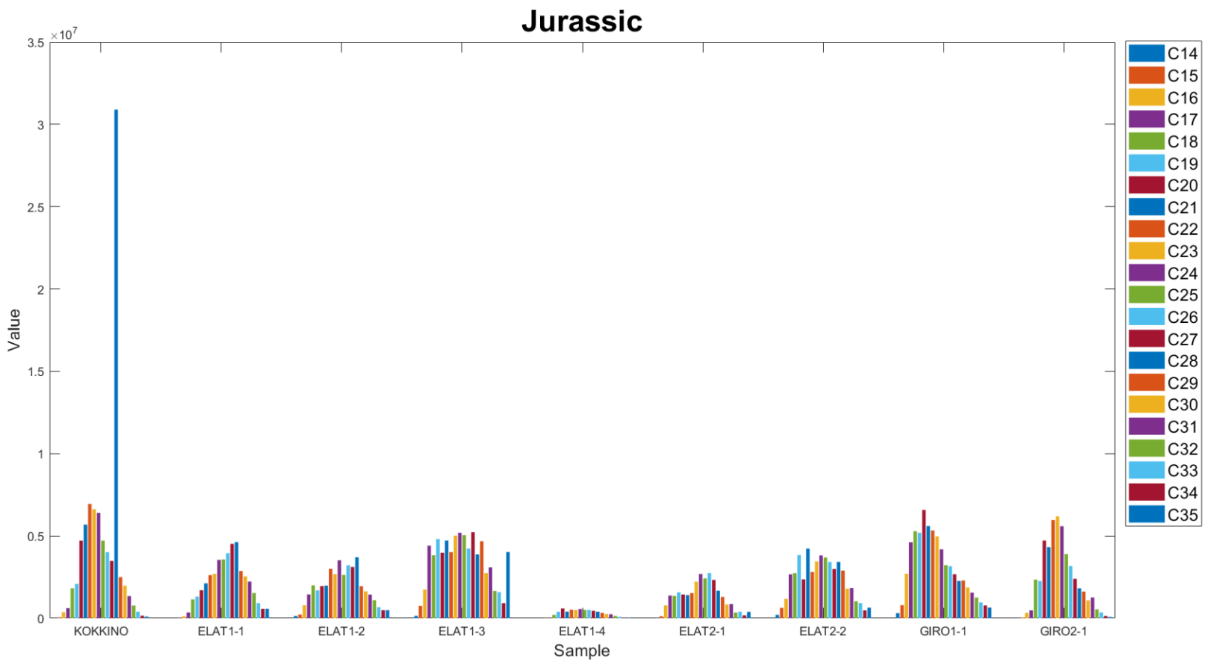
```
bar(paper10_normal,'Parent', axes4);
title('Pantokrator Limestone','FontName','Arial','FontWeight','bold','FontSize',25);
xlabel('Sample','FontSize',14);
ylabel('Value','FontSize',14);
h = legend(Component_names);
set(h, 'FontSize',14);


%% Box Plot of All Alkanes data
sub_c2 = 5;
sub_r2 = 1;
n_pages2 = nc/(sub_r2*sub_c2);
n_pages2 = ceil(n_pages2);

for j  =  1:n_pages2;
    figure;
    k = (j-1)*(sub_r2*sub_c2)+1;
    for i  = k:k+(sub_r2*sub_c2)-1;
        subplot(sub_r2,sub_c2,i-(sub_r2*sub_c2)*(j-1)),
boxplot(justData(:,i)/max(justData(:,i)));
        grid on
        title(Component_names{i}, 'FontSize', 12);
    end
end


%% Alkanes Data by Age
[Data,Labels] = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx', 4,'A3:AT71');
[justData,justLabels] = xlsread('G:\Masters Thesis stuff\Western Greece Database.xlsx',
4,'F3:AT71');

Component_names = Labels(1, 7:28);

Jurassic = Data(1:9,7:28);
Oligocene = Data(10:14,7:28);
Neogene = Data(15:31,7:28);
Miocenept1 = Data(32:40, 7:28);
Miocenept2 = Data(41:53, 7:28);
Pliocenept1 = Data(54:61,7:28);
Pliocenept2 = Data(62:68,7:28);

Jurassic_sum = Data(1:9, 46);
Oligocene_sum = Data(10:14, 46);
Neogene_sum = Data(15:31, 46);
Miocenept1_sum = Data(32:40, 46);
Miocenept2_sum = Data(41:53, 46);
Pliocenept1_sum = Data(54:61, 46);
Pliocenept2_sum = Data(62:68, 46);

Jurassic_normal = Jurassic./Jurassic_sum;
Oligocene_normal = Oligocene./Oligocene_sum;
Neogene_normal = Neogene./Neogene_sum;
Miocenept1_normal = Miocenept1./Miocenept1_sum;
Miocenept2_normal = Miocenept2./Miocenept2_sum;
Pliocenept1_normal = Pliocenept1./Pliocenept1_sum;
Pliocenept2_normal = Pliocenept2./Pliocenept2_sum;

Jurassic_Sample_names = Labels(2:10,6);
Oligocene_Sample_names = Labels(11:15,6);
Neogene_Sample_names = Labels(16:32,6);
Miocene_Sample_namespt1 = Labels(33:41,6);
Miocene_Sample_namespt2 = Labels(42:54,6);
Pliocene_Sample_namespt1 = Labels(55:62,6);
Pliocene_Sample_namespt2 = Labels(63:69,6);
```

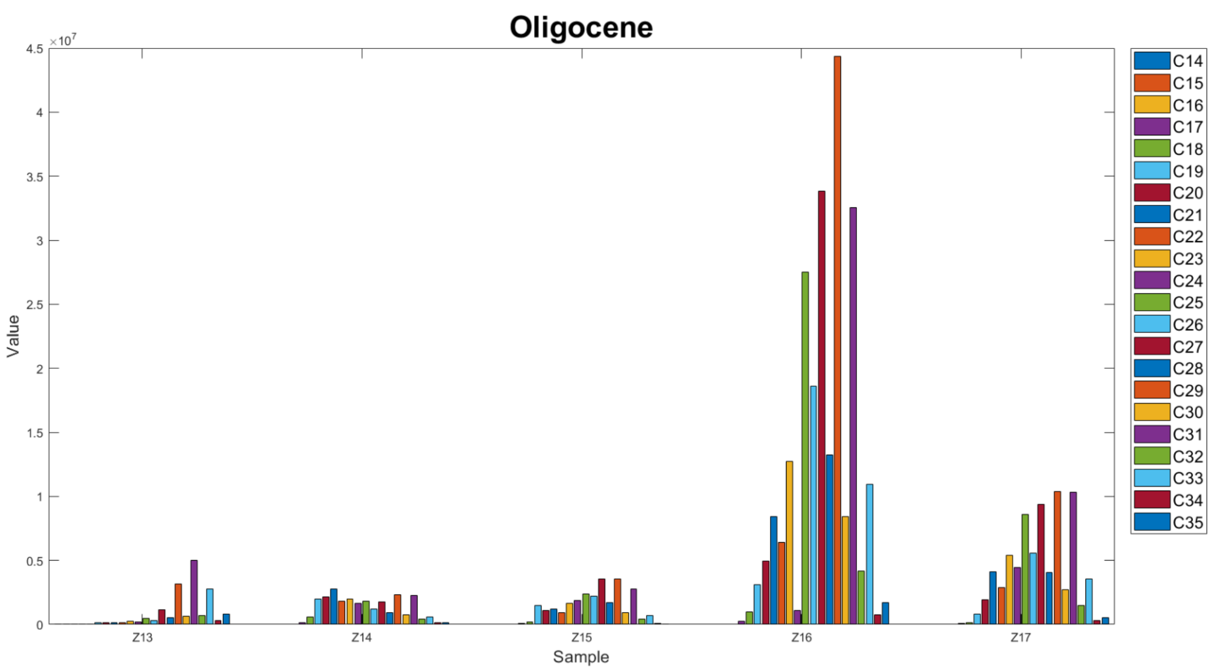
```
%% Bar-chart of Alkanes Data by Age
[nx,ny] = size(Component_names);
Tick = [1:ny];
axes1  =  axes('Parent', figure,'XTickLabel', Jurassic_Sample_names,'XTick', Tick);
box(axes1,'on');
hold(axes1,'all');
xlabel('Sample','FontSize',14);
ylabel('Value','FontSize',14);
bar(Jurassic_normal,'Parent', axes1);
title('Jurassic','FontName','Arial','FontWeight','bold','FontSize',25);
xlabel('Sample','FontSize',14);
ylabel('Value','FontSize',14);
h = legend(Component_names);
set(h, 'FontSize',14);
hold on;

axes2  =  axes('Parent', figure,'XTickLabel', Oligocene_Sample_names,'XTick', Tick);
box(axes2,'on');
hold(axes2,'all');
bar(Oligocene_normal,'Parent', axes2);
title('Oligocene','FontName','Arial','FontWeight','bold','FontSize',25);
xlabel('Sample','FontSize',14);
ylabel('Value','FontSize',14);
h = legend(Component_names);
set(h, 'FontSize',14);

axes3  =  axes('Parent', figure,'XTickLabel', Neogene_Sample_names,'XTick', Tick);
box(axes3,'on');
hold(axes3,'all');
bar(Neogene_normal,'Parent', axes3);
title('Neogene','FontName','Arial','FontWeight','bold','FontSize',25);
xlabel('Sample','FontSize',14);
ylabel('Value','FontSize',14);
h = legend(Component_names);
set(h, 'FontSize',14);

axes4  =  axes('Parent', figure,'XTickLabel', Miocene_Sample_namespt1,'XTick', Tick);
box(axes4,'on');
hold(axes4,'all');
bar(Miocenept1_normal,'Parent', axes4);
title('Miocene','FontName','Arial','FontWeight','bold','FontSize',25);
xlabel('Sample','FontSize',14);
ylabel('Value','FontSize',14);
h = legend(Component_names);
set(h, 'FontSize',14);

axes5  =  axes('Parent', figure,'XTickLabel', Miocene_Sample_namespt2,'XTick', Tick);
box(axes5,'on');
hold(axes5,'all');
bar(Miocenept2_normal,'Parent', axes5);
title('Late Miocene','FontName','Arial','FontWeight','bold','FontSize',25);
xlabel('Sample','FontSize',14);
ylabel('Value','FontSize',14);
h = legend(Component_names);
set(h, 'FontSize',14);

axes6  =  axes('Parent', figure,'XTickLabel', Pliocene_Sample_namespt1,'XTick', Tick);
box(axes6,'on');
hold(axes6,'all');
bar(Pliocenept1_normal,'Parent', axes6);
title('Early Pliocene','FontName','Arial','FontWeight','bold','FontSize',25);
xlabel('Sample','FontSize',14);
ylabel('Value','FontSize',14);
h = legend(Component_names);
set(h, 'FontSize',14);

axes7  =  axes('Parent', figure,'XTickLabel', Pliocene_Sample_namespt2,'XTick', Tick);
box(axes7,'on');
hold(axes7,'all');
bar(Pliocenept2_normal,'Parent', axes7);
title('Pliocene','FontName','Arial','FontWeight','bold','FontSize',25);
```

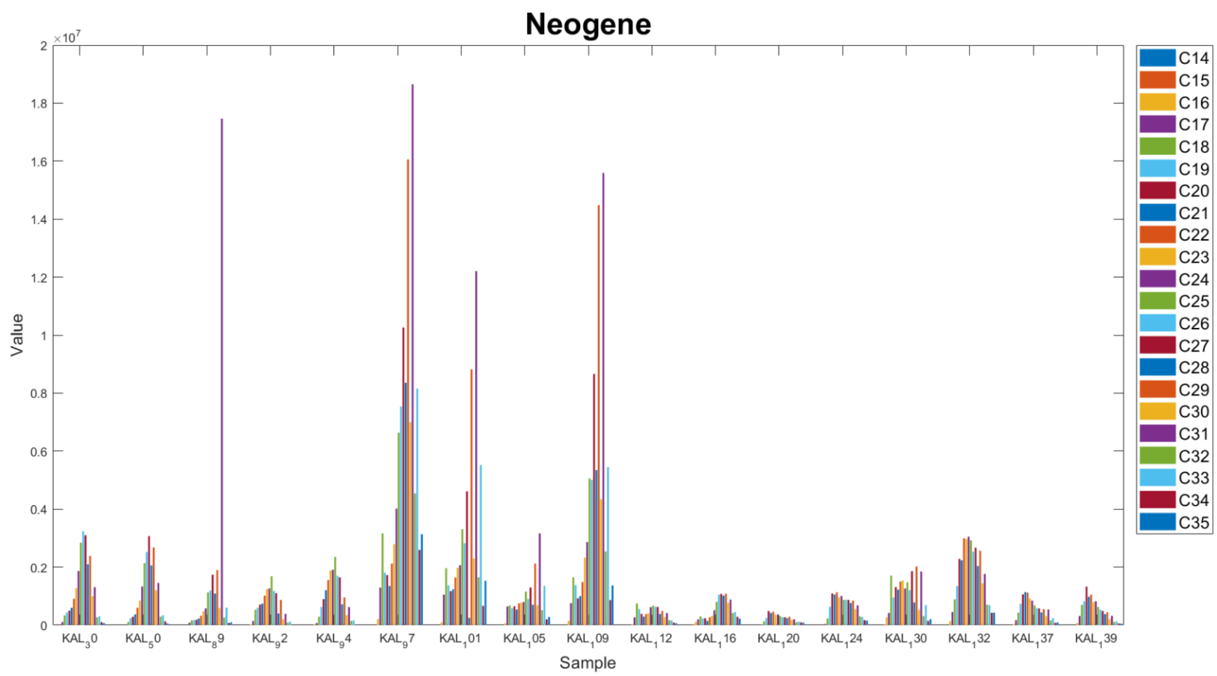
```
xlabel('Sample','FontSize',14);
ylabel('Value','FontSize',14);
h = legend(Component_names);
set(h, 'FontSize',14);
```

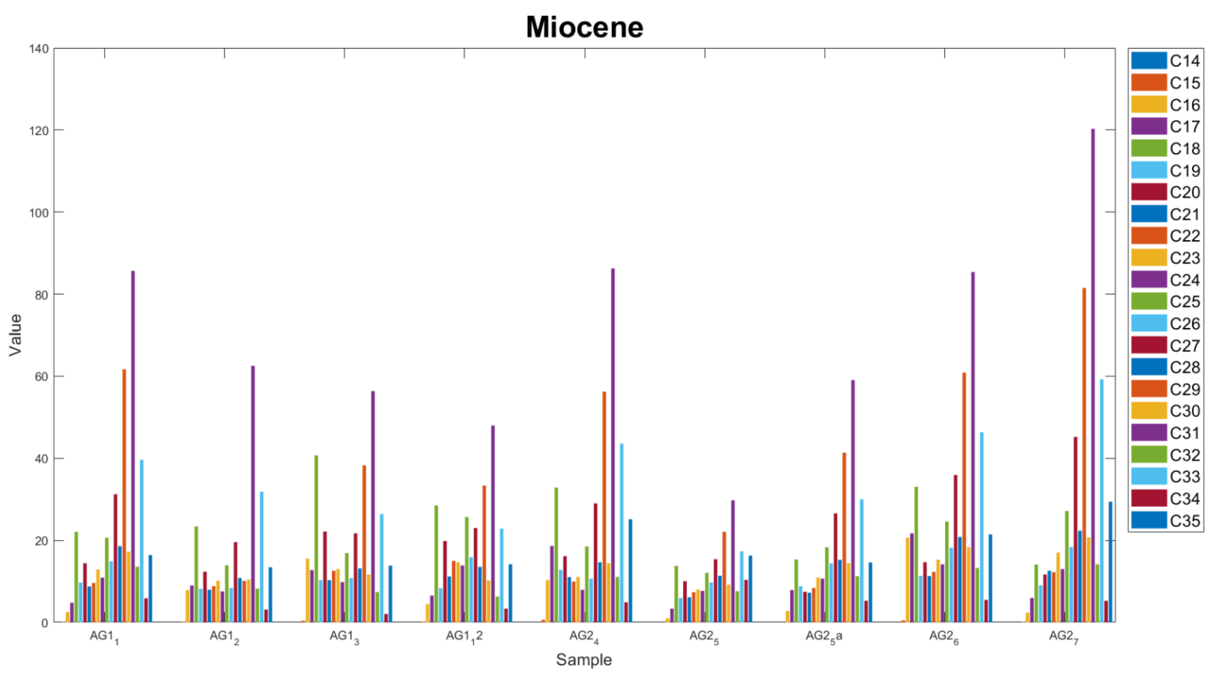
Original Bar Charts

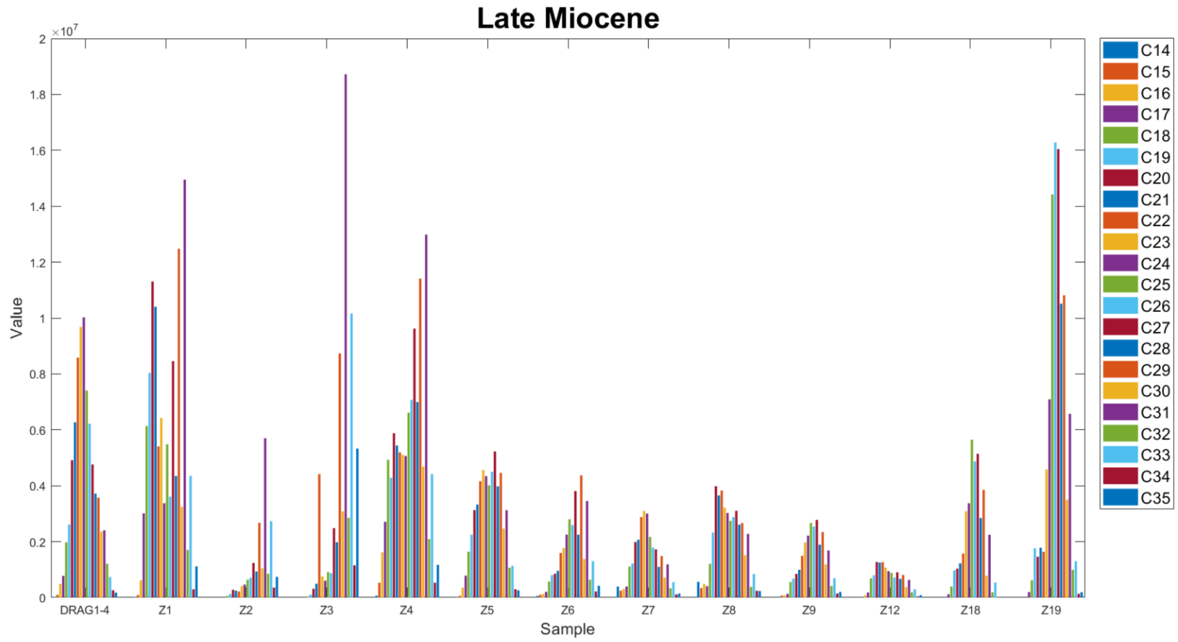
By Age

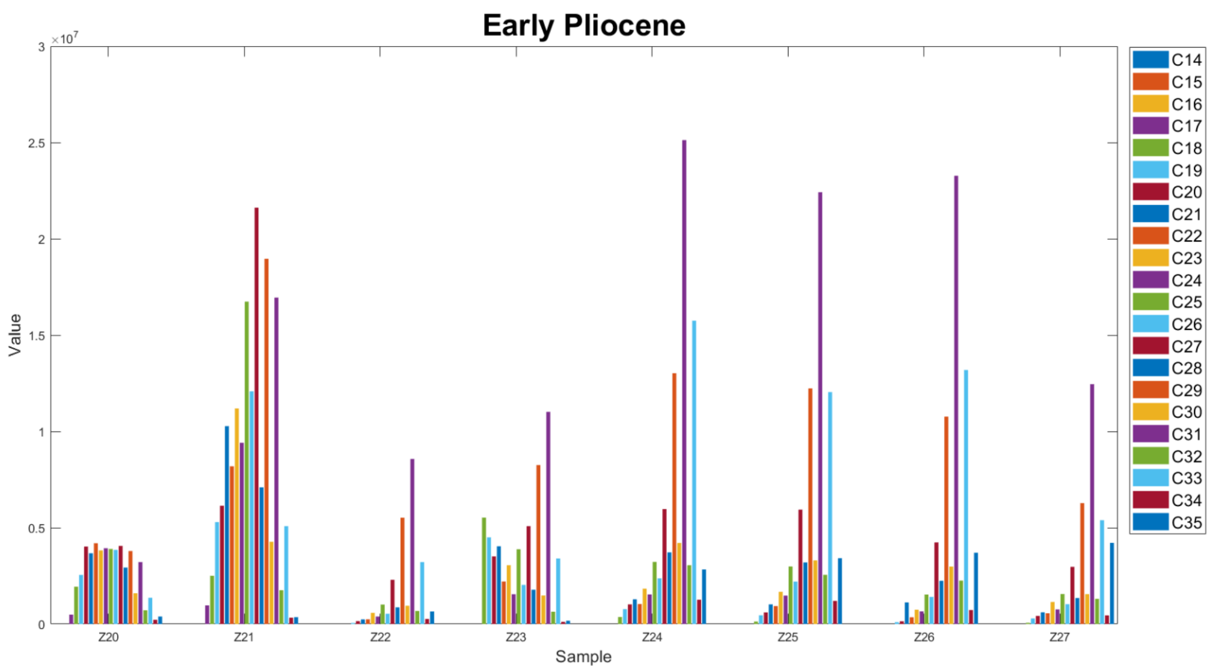


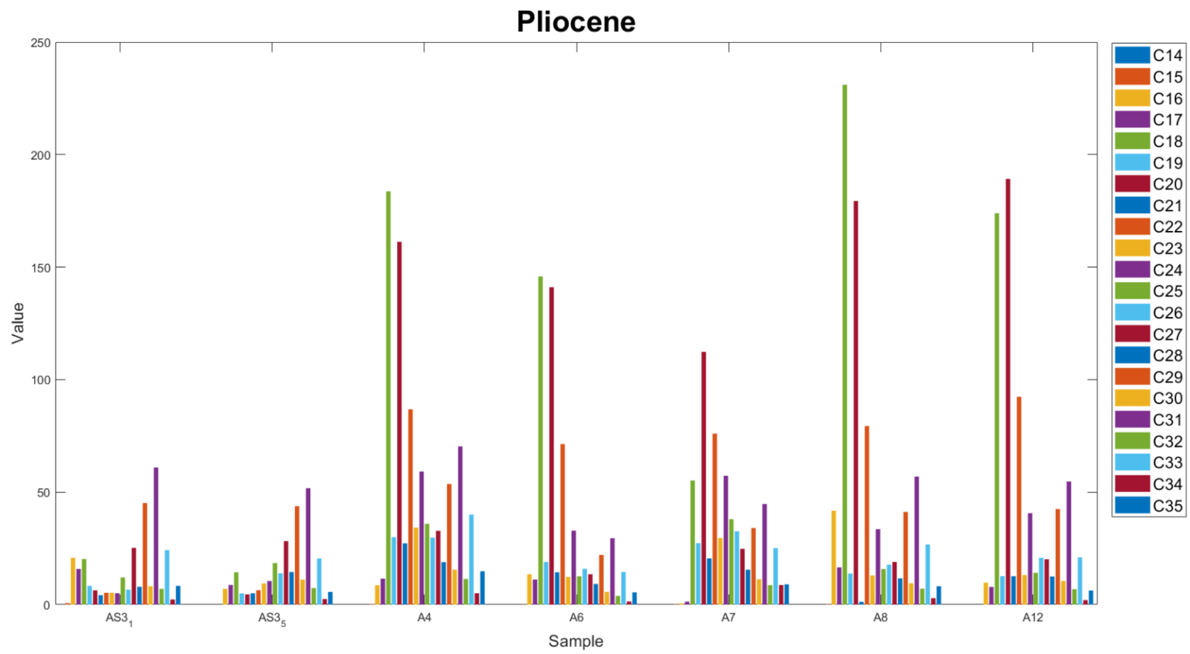



Neogene
Value
Sample
C14
C15
C16
C17
C18
C19
C20
C21
C22
C23
C24
C25
C26
C27
C28
C29
C30
C31
C32
C33
C34
C35


Miocene
Value
Sample
C14
C15
C16
C17
C18
C19
C20
C21
C22
C23
C24
C25
C26
C27
C28
C29
C30
C31
C32
C33
C34
C35

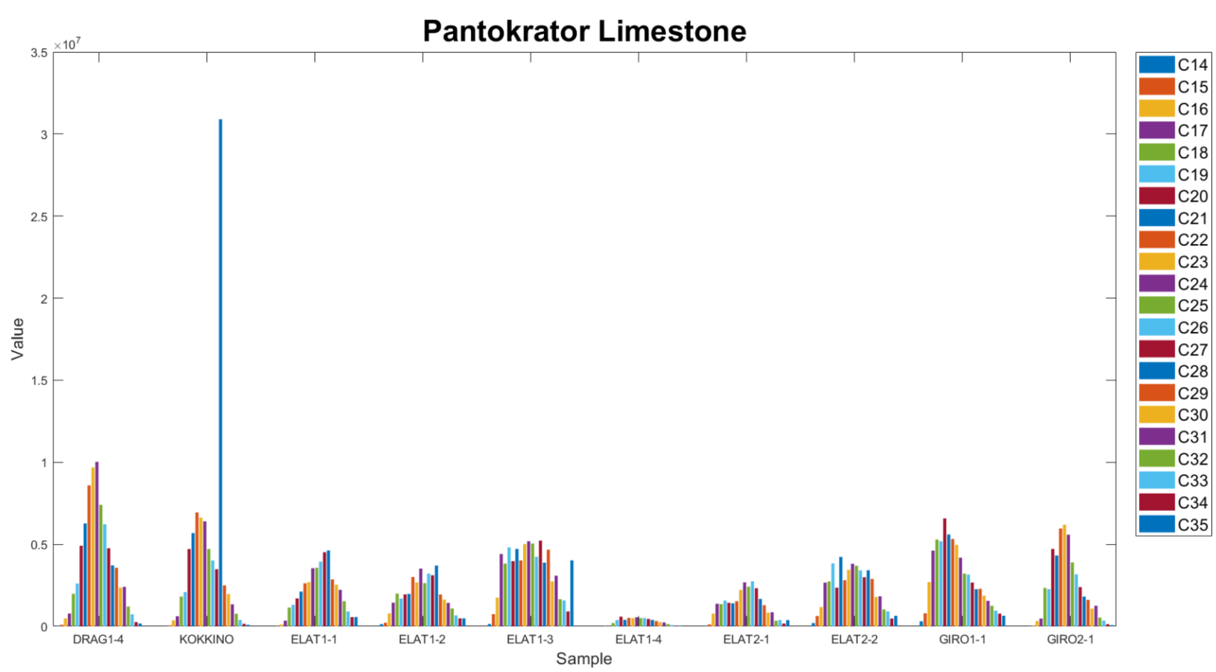

Late Miocene
×10^7
Value
Sample
DRAG1-4
Z1
Z2
Z3
Z4
Z5
Z6
Z7
Z8
Z9
Z12
Z18
Z19
C14
C15
C16
C17
C18
C19
C20
C21
C22
C23
C24
C25
C26
C27
C28
C29
C30
C31
C32
C33
C34
C35


Early Pliocene
×10^7
Value
Sample
Z20
Z21
Z22
Z23
Z24
Z25
Z26
Z27
C14
C15
C16
C17
C18
C19
C20
C21
C22
C23
C24
C25
C26
C27
C28
C29
C30
C31
C32
C33
C34
C35

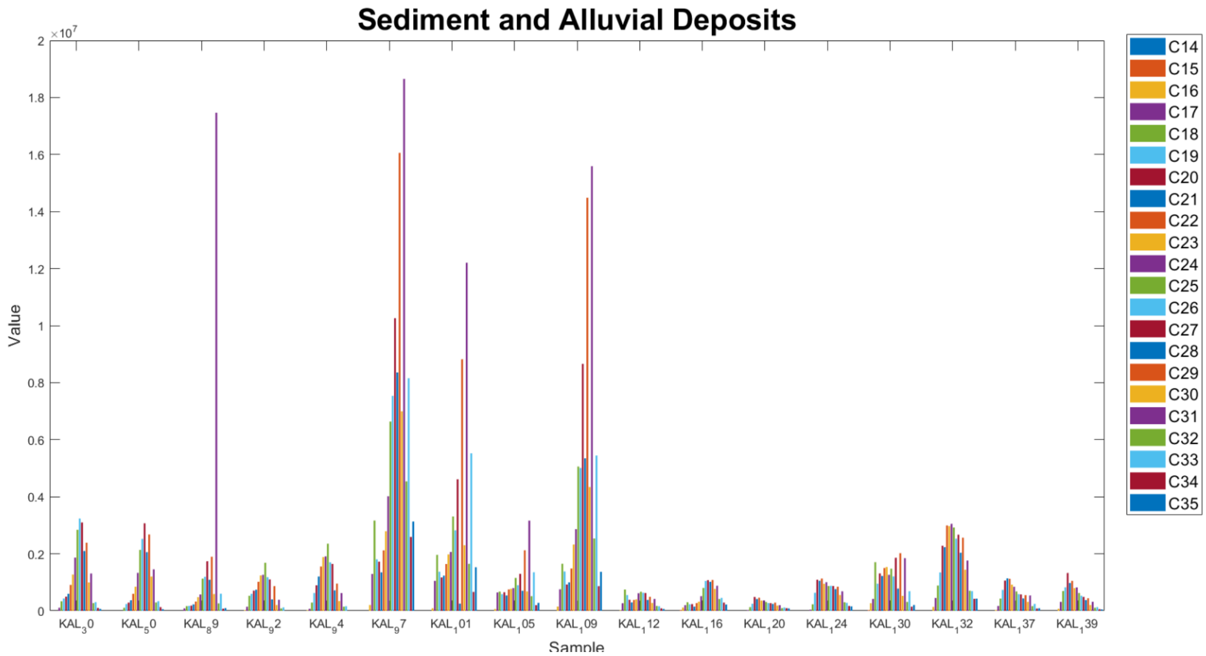


By Diploma Thesis:

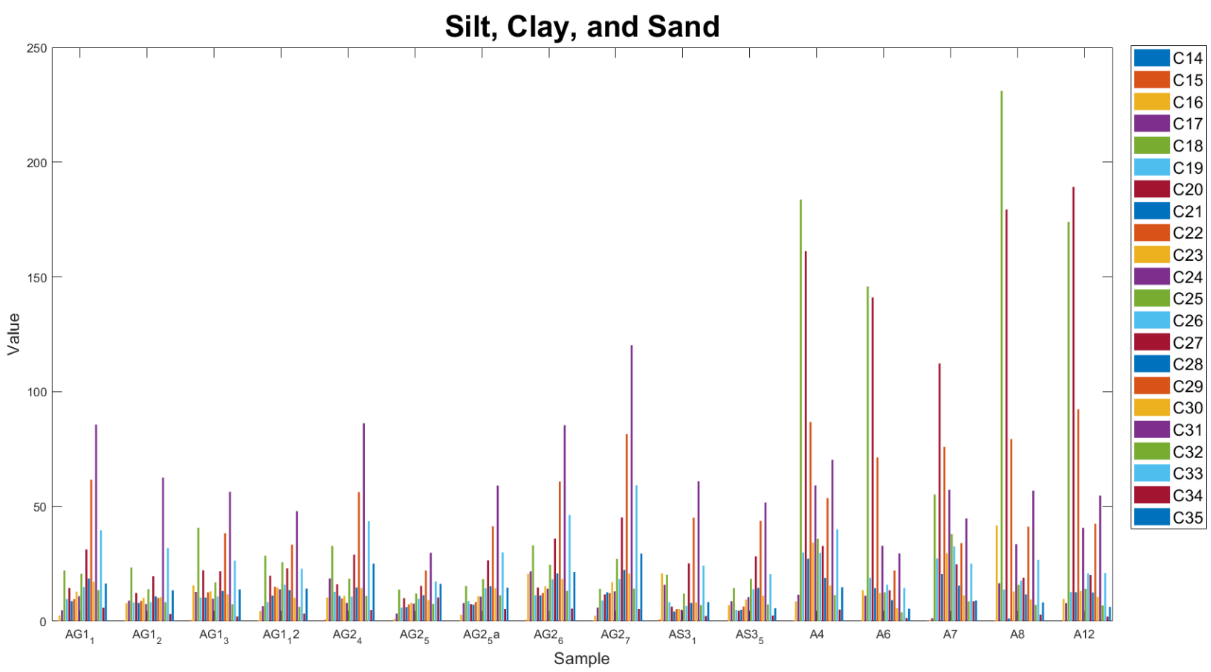
Kolokotini



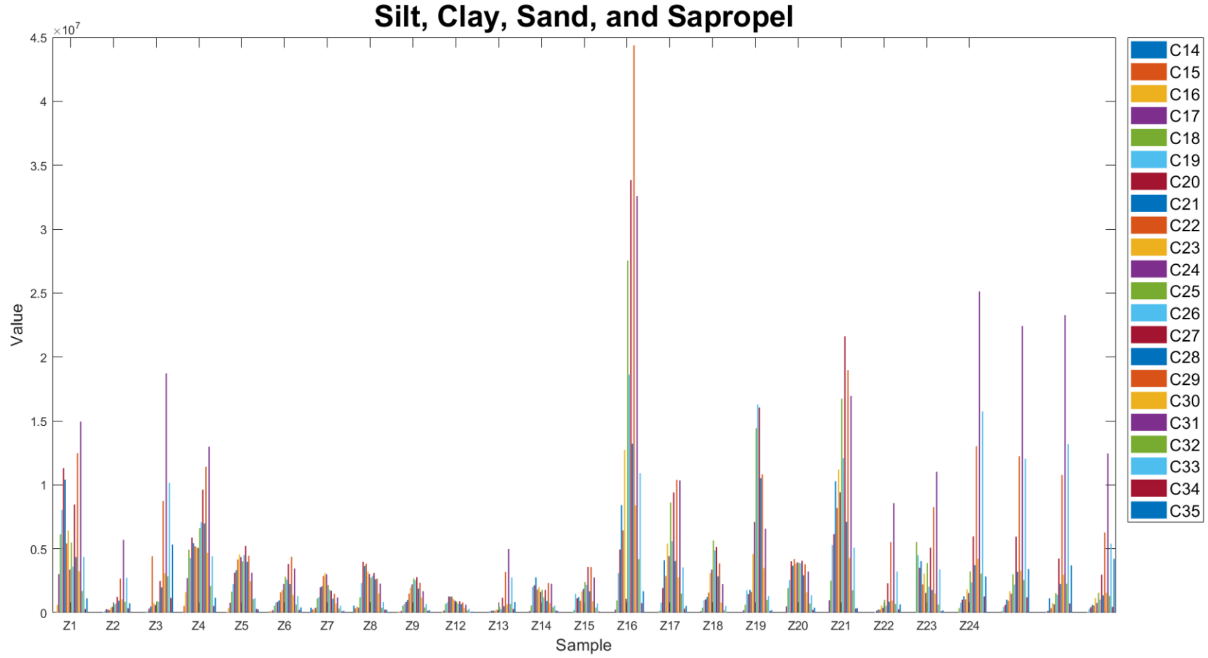
Tsochantaris



Papoulas



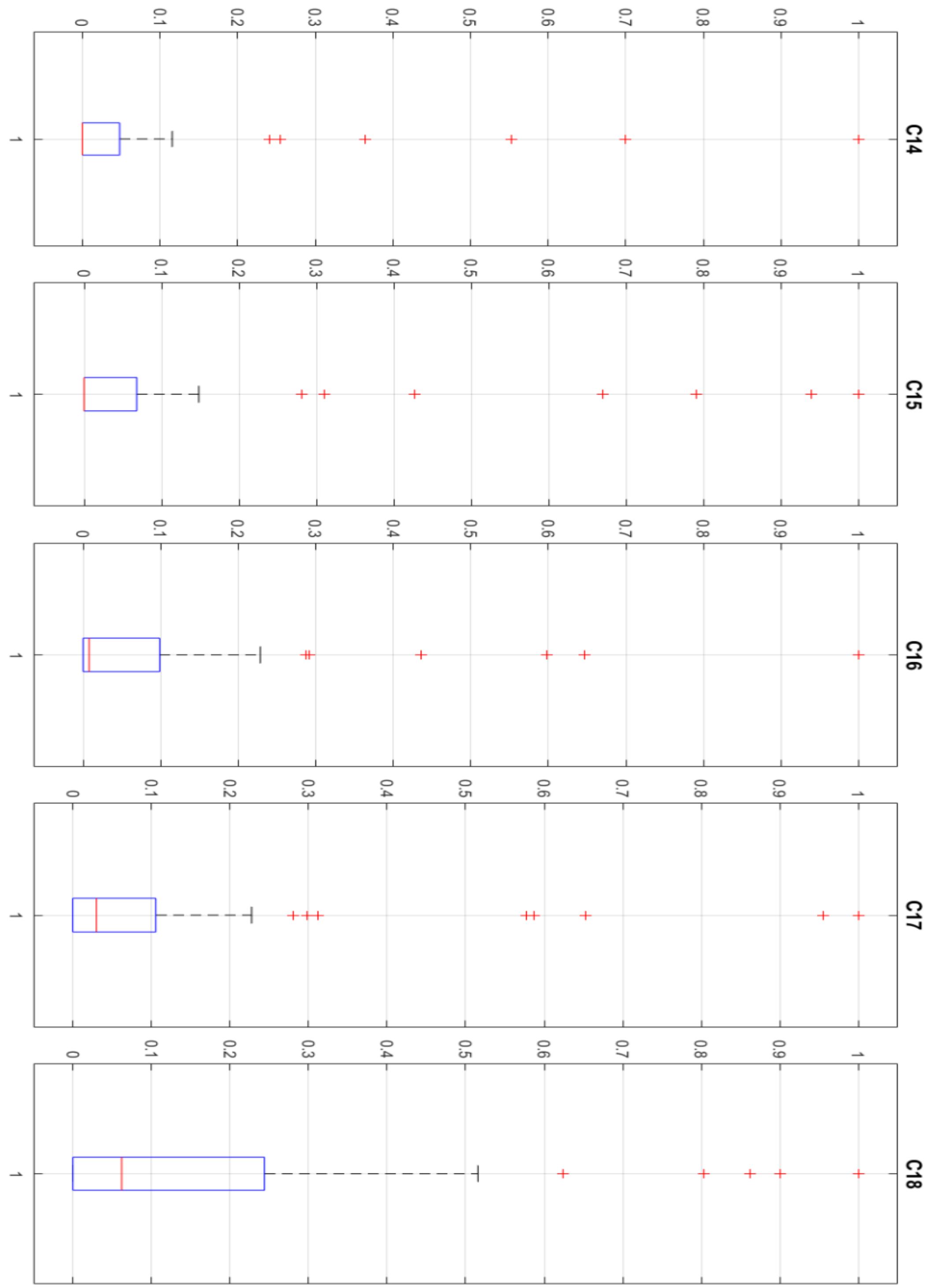
Koukounya



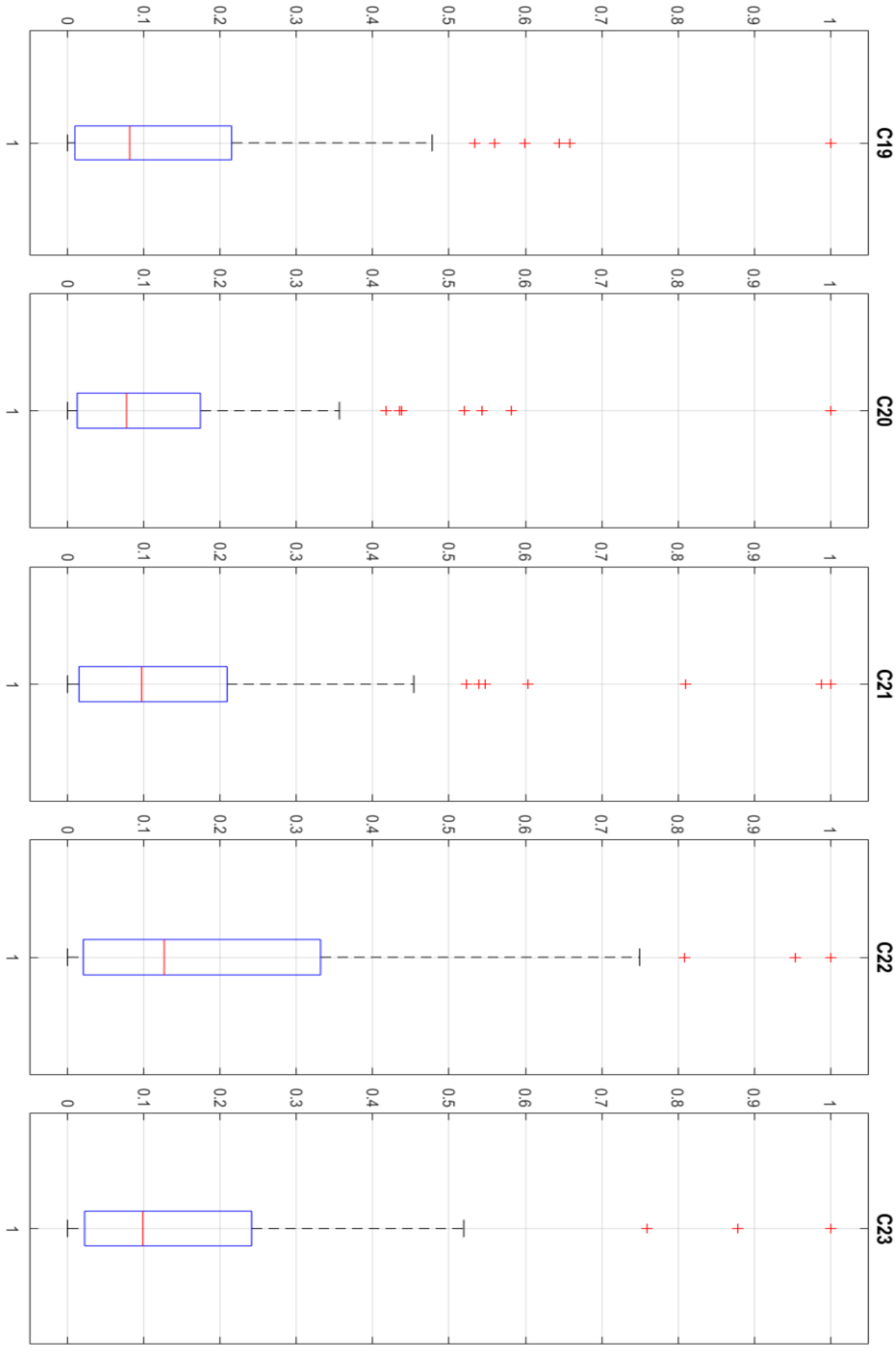
Silt, Clay, Sand, and Sapropel
Value
Sample
Z1
Z2
Z3
Z4
Z5
Z6
Z7
Z8
Z9
Z12
Z13
Z14
Z15
Z16
Z17
Z18
Z19
Z20
Z21
Z22
Z23
Z24
C14
C15
C16
C17
C18
C19
C20
C21
C22
C23
C24
C25
C26
C27
C28
C29
C30
C31
C32
C33
C34
C35

Box Plots

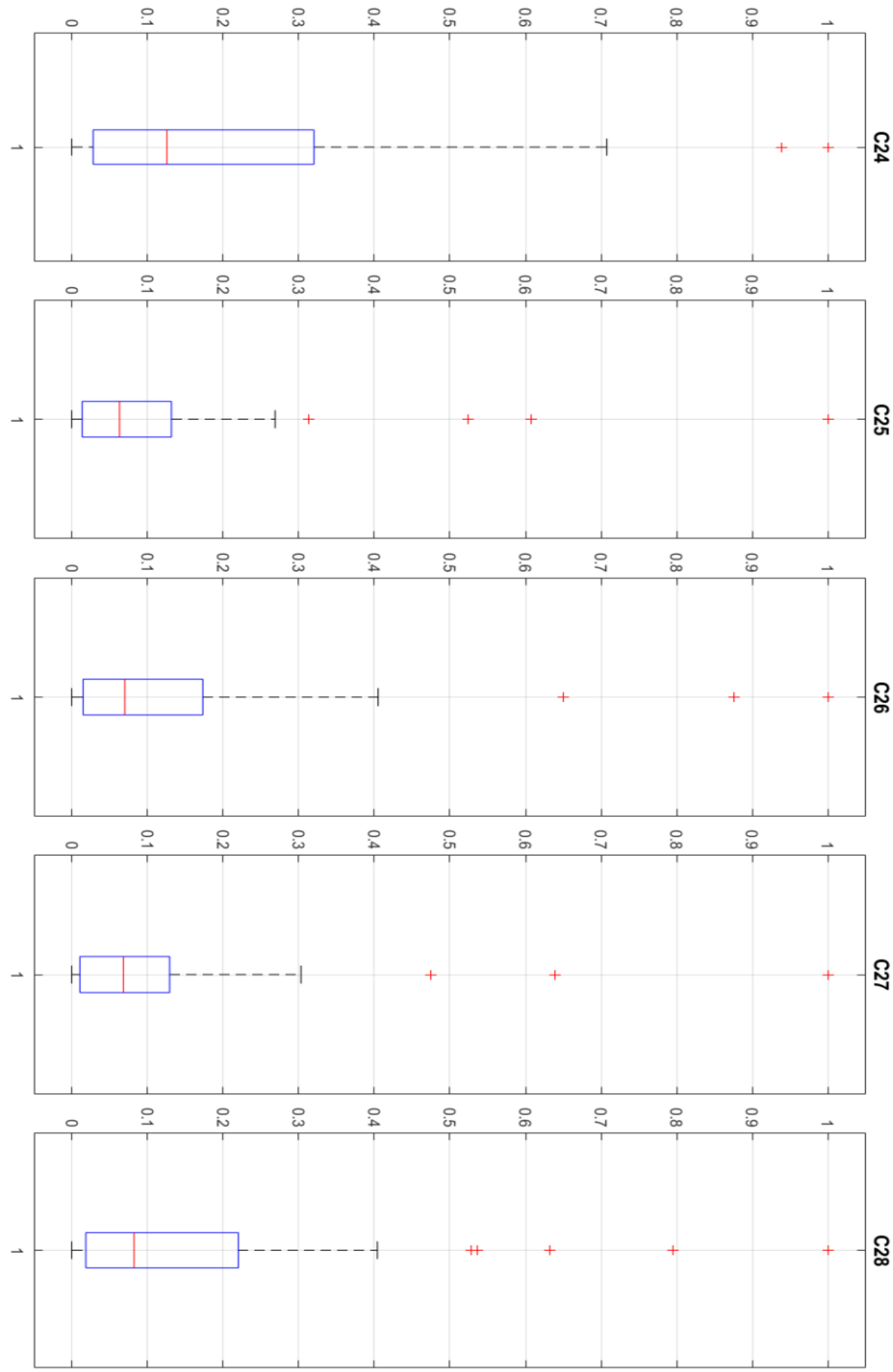
C14-C18



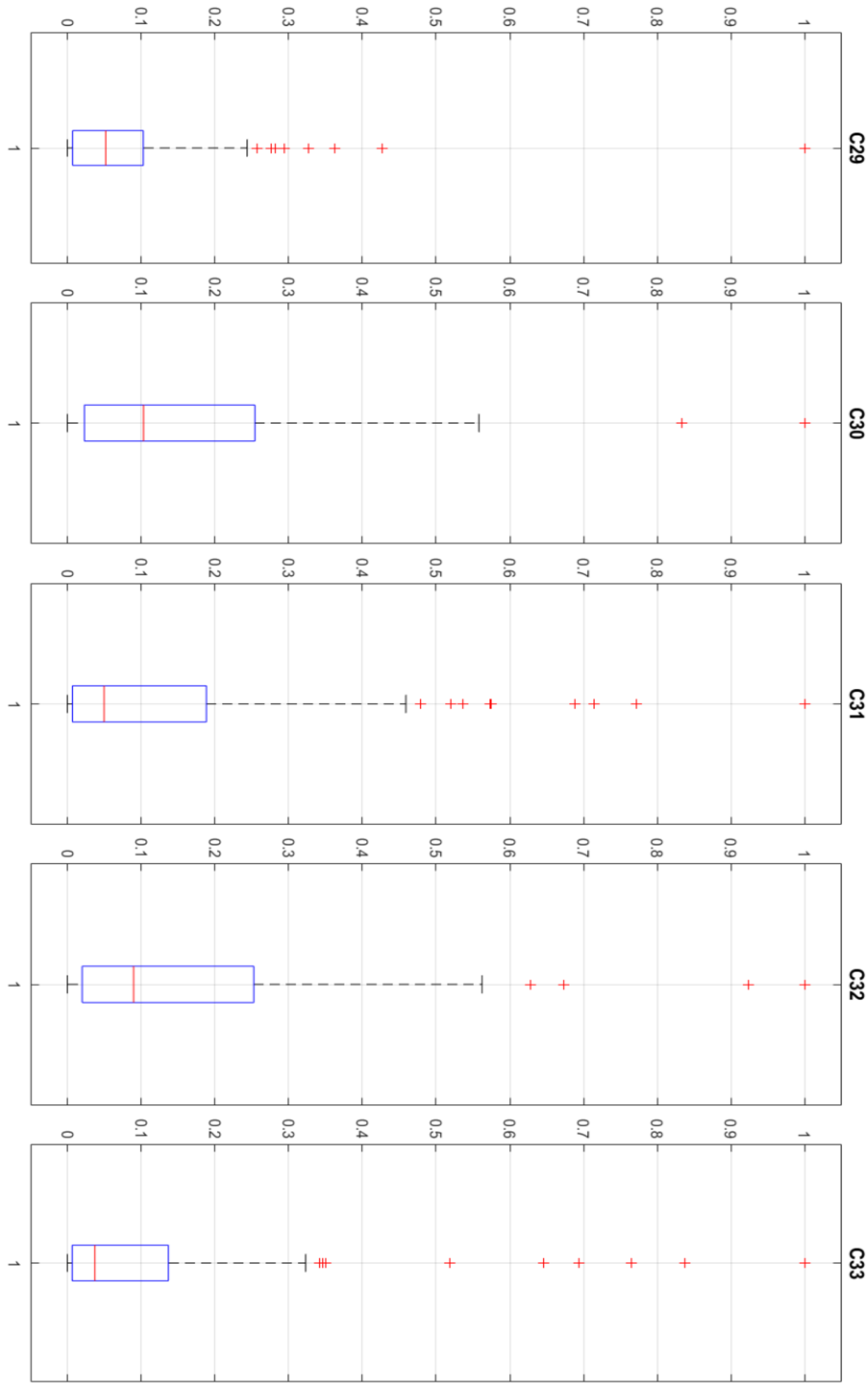
C19-C23



C24-C28



C29-C33



C34-C35