# Clarification of the term “Aged Peat”

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for

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## EXECUTIVE SUMMARY:

This report responds to the question of whether "aged peat" is an accurate description of the substance mined and processed by Humatech, Inc. for use in animal feed. Certain geologic processes must occur in order for aged peat to form, and these processes are distinct from those processes which form lignite, Leonardite, oil shale, subbituminous coal, and bituminous coal.

To define aged peat and to distinguish it from other earth layers, relevant geologic processes will be examined. Geologic processes are the same worldwide and across geologic time. Geoscientists are able to describe how these geologic processes grow the sedimentary column in a certain area for each type of sedimentary column. Modern geologic processes provide an analog to ancient geologic processes. While sedimentary columns differ across the earth, there are similarities. Geoscientists apply their knowledge of modern and ancient analog sedimentary growth to understand how the sedimentary column grows in a specific region.

The study of stratigraphic growth across time is known as sequence stratigraphy. Sequence stratigraphy identifies how tectonic movements, changing sea levels, and sediment supply are the drivers which combine to create repeating cycles, defining how layers of earth sediment are deposited over time (chronostratigraphically). This stratigraphic growth defines how certain materials, like peat and coal, are created. Again, the main drivers of stratigraphic growth are tectonic activity (like plate movements and thermal cooling of continents), eustasy (world wide and local sea level changes), and sediment supply (including the growth of plants in swamps and marshes). These drivers will be defined in detail later in this report, and applied to understanding the formation of aged peat for several analogous regions throughout the world.

In a very general sense, the geologic processes and timing required to form aged peat are:

- extensive vegetation (especially trees with high acid and low pH);
- geologically rapid inundation of this vegetation by sea level rise or burial and thermal maturation; and
- only partial decomposition.

In the same general sense, the formation of lignite (or Leonardite) requires:

- extensive vegetation (less acid and high pH);
- increased pressure and heating from burial; and
- chemical transformation of peat to a brown-black rock with a higher carbon content, which will burn.

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| Sections 4.0 & 4.1 | Description of sequence stratigraphy and associated geologic drivers. |
| Section 4.2 | Power of sequence stratigraphy to show how aged peat is formed at different locations. |
| Sections 4.2.1 & 4.2.2 | Two specific analog aged peat formations: (1) General Case; (2) Campos Basin, Brazil. |
| Section 4.2.3 | Fruitland Formation in the San Juan Basin of New Mexico. |
| Section 4.2.4 | Blackhawk Formation in the Four-Corners Area. |
| Section 4.2.6 | Sequence Stratigraphy explanation of the peat and bituminous coal at Humatech's current New Mexico mining location, showing the material mined by Humatech is aged peat and distinct from lignite, Leonardite, or Subbituminous or Bituminous Coal. |
| Section 5.0 | Summary of results. |
| Section 6.0 | Conclusion: "aged peat" is an appropriate name, geologically, for the material Humatech is mining. |
| Appendix 1 | Defines key geologic terms used in the document. |
| Appendix 2 | Figures. |

Table 1: Overview by Section

The aged peat Humatech is currently mining is overlain by limestone (which partially shielded it from the temperatures and pressures of burial). In addition, this aged peat has patterns from the wood (but no fibers) from which it is formed, has high humic acid content, and is not combustible, making it is distinguishable from lignite or Leonardite, which is a brown-black coal rock, which is not as acidic, and which does burn.

After defining relevant geologic terms and processes, explaining how these processes form aged peat, and studying analogous aged peat formations, this report concludes that "aged peat" is an appropriate geologic name for the material Humatech is currently mining and plans to mine in the future.

Table 1 summarizes important sections, in order to make relevant information in this document more accessible. Note that definitions for geologic terms and all figures are found in the Appendix.

# Contents

# 1 Introduction

> Peat and aged peat are naturally occurring substances found both in the earth and in the waters of ponds, streams, and rivers, and as a result has always been a constituent of the diets of animals and humans. As a natural substance, peat is of varying composition depending on the source plant species, moisture levels, climate, and other factors.[1]

Humatech, Inc. is mining aged peat, which differs from fresh peat or reed-sedge peat in that it does not contain fibers. Peat, and aged peat can be found in several geologic formations around the globe. Peat, in general, is the first stage in the formation of coal. Lignite, Leonardite, Subbituminous Coal, Bituminous Coal, and Anthracite Coal are later stages in the formation of coal, which are generally prescribed as being formed by the increased temperature and pressure associated with burial of extensive bog developed vegetation by stratigraphic depositional processes. Table 2 in Section 3.1 highlights physical characteristics of these different stages in the development of aged peat, lignite, Leonardite, subbituminous coal, bituminous coal, and anthracite coal.[2]

Under certain conditions, all gaseous components of peat are lost as it ages and the result is lignite, or coal. Under other conditions, aged peat maintains significant concentrations of these volatile substances including the humic acids. It is this aged peat which has been widely studied as a component of animal feeds.

# 2 Objective

This document will establish “aged peat” as a common and usual name for the product produced by Humatech, Inc. by geologically defining the substance and thereby setting it apart from oil shale, lignite, subbituminous coal, bituminous coal, or anthracite.

[1] Summary Report of the Expert Panel: Generally Recognized as safe status use of aged peat in feed for food-producing animals, September 2010, pages 2-3.

[2] Reading summary and http://geology.com/rocks/coal.shtml

# 3 Summary of Distinctions Between Aged Peat, Lignite, Bituminous Coal and Anthracite Coal

## 3.1 Formation Distinctions of Peat, Lignite, Bituminous Coal, and Anthracite Coal

Peat, aged peat, lignite, and various types of coal beds each consist of altered plant remains. When a forested swamp is inundated by rising sea level, the process of coal formation begins. Formation of peat, lignite, and coal, starts with heavy vegetation growth. The debris must be buried, compressed, and protected from erosion. Even though all the biological, geographic and climatic factors may be favorable, coal will not be formed unless the plant debris was submerged and buried by sediments. Geologists often refer to four stages in coal formation: peat, lignite, bituminous coal, and anthracite coal.[3] The stage depends upon the conditions to which the plant remains are subjected after they were buried - the greater the pressure and heat, the higher the rank of coal. Higher-ranking coal is denser and contains less moisture and gases and has a higher heat value than lower-ranking coal, as described below.[4]

Peat is the first stage in the formation of coal. Normally, vegetation is oxidized to water and carbon dioxide. However, if plant material accumulates underwater, oxygen is not present, and only partial decomposition occurs, the accumulation of peat occurs. Peat is fibrous, soft, and can be spongy. Plant remains are easily recognizable. Geologically recent peat deposits contain a large amount of water and must be dried before use. Therefore, it is seldom used as a source of heat, since, if peat burns, it burns with a long flame and considerable smoke.

Aged peat is much older, fibers have decomposed, and there is a concentration of humic and fulvic acids as a result of the decomposition process. It is not spongy like peat, but rather crumbles easily. Aged peat does not burn.

Lignite (and a derivative known as Leonardite in North Dakota and Wyoming) is often referred to as the second stage of coal formation, and is formed when peat is subjected to increased vertical pressure from accumulating sediments. Lignite is typically dark brown to black in color and, can contain traces of plants. It is not a very efficient fuel and crumbles easily. Lignite does burn, and creates problems when it burns underground.

Bituminous “soft” coal is referred to as the third stage. Added pressure has made

[3]The History of Mining in Cape Breton, http://www.minersmuseum.com/hof_mining_coal_formation.htm
[4]The History of Mining in Cape Breton, http://geology.com/rocks/coal.shtml

it compact and virtually all traces of plant life have disappeared. It burns and is widely used in industry as a source of heat energy.

Anthracite is the fourth stage in coal formation, and is also known as "hard coal" because it is hard and has a high luster. It appears to have been formed as a result of combined pressure and high temperature. Anthracite burns with a short flame and little smoke. There is seldom anthracite where there are peat beds.

## 3.2 Physical and Chemical Distinctions

Peat, aged peat, lignite, Leonardite, subbituminous coal, bituminous coal, and anthracite coal are chemically and physically different substances. Table 2 summarizes the *chemical* and *physical* differences between aged peat and these other substances.

| **Properties** | **Fresh Peat** | **Aged Peat** | **Lignite** | **Leonardite** | **Subbituminous Coal** | **Bituminous Coal** | **Anthracite Coal** |
|---|---|---|---|---|---|---|---|
| Accommodation Rate / Peat Production rate | equal | slightly greater than | equal | equal | equal | equal | equal |
| Acidity (dependent on Sulpher) | high | high | medium | medium | medium | low | low |
| Clay | little | some | little | little | none | none | none |
| Fibrous & Spongy | x | | | | | | |
| Soft Crumble | | x | x | | | | |
| Hard Crumble | | | x | x | | | |
| Rock | | | x | x | x | x | x |
| Dry Ash Free Basis | <60% | 60% | 60%-70% | 60%-70% | 71%-77% | 77%-87% | >87% |
| Combustibility | long flame & much smoke | none | inefficient <8300 BTU | inefficient, low BTU | yes 13,000 BTU | most abundant fuel | short flame & little smoke |

Table 2: Rock Properties

### 3.3 Stratigraphic Distinctions

Section 4 provides a more detailed explanation of sequence stratigraphy and its application to the definition of aged peat. As a summary, the following describes the *stratigraphic* differences between the aged peat and lignite/coals.

The general geologic processes and timing required to form aged peat are:

- extensive vegetation (especially trees with high acid and low pH);
- geologically rapid inundation of this vegetation by sea level rise or burial; and
- only partial decomposition.

In the same general sense, to form lignite (or Leonardite), requires

- extensive vegetation (less acid and high pH);
- increased pressure and heating from burial; and
- chemical transformation of peat to a brown-black rock with a higher carbon content, which will burn.

## 4 Sequence Stratigraphy

Sequence stratigraphy is the study of the sedimentary depositional cycles which occur because of changing sea levels or eustasy. Sedimentation growth, like tree ring growth, happens over time. This growth is driven by tectonics, eustasy, sediment supply, and other geological forces as described in Section 4.1. One of the wonders of modern geologic understanding is the fact that the cycles we observe in the recent geologic record have been repeated throughout geologic time. The result is modern fresh peat bogs can be directly related as analog examples to ancient aged peat deposits. Once we understand the sequence of how certain deposition occurs in one region at one time, we can then use this as an analog in other regions to confidently predict similar deposition. Understanding stratigraphic growth provides a powerful tool for defining how materials like aged peat and lignite were created.

Sedimentary geology is laid down in layers. The process of sediment deposition defines the geology at the location of the Humatech mine. Figure 1 shows the geology of the Grand Staircase, which is just northwest of the area of interest in the San Juan Basin, and illustrates the layering of sedimentary geology. The geology of this area is well known because it includes (A) the Grand Canyon, (B) the Chocolate Cliffs, (C) the Vermilion Cliffs, (D) the White Cliffs, (E) Zion Canyon, (F) the Gray Cliffs, (G) the Pink Cliffs, and (H) Bryce Canyon. Studying the basic stratigraphic growth layering process is known as sequence stratigraphy. The example area where the current Humatech mine is located is in the San Juan Basin (see Figure 2),[5] and the time interval is the Cretaceous (see Figure 3)[6] Fruitland Formation (see Figure 4).[7]

To provide a general view of the geological time frame when the type of aged peat mined by Humatech was formed, Figure 5 summarizes Cretaceous sequence stratigraphy from 66 million years ago to over 98 million years ago.[8] The relative changes in coastal onlap, which are directly related to eustasy, are shown in the sixth column from the left in the figure.

When in-depth geological analysis (core sampling, seismic data, etc.) of a specific area is not available through academic and commercial sources, sequence stratigraphy principles can be applied. Thus, through sequence stratigraphy and documented geological processes and sequences from other regions, we can positively identify the similar geological processes and sequences in a study area of interest. This concept will be applied within the scope of this document by reviewing the formation of aged peat in:

1. a general case (Section 4.2.1),
2. historical cases in regions of Brazil, New Mexico, and Utah (Section 4.2.2, 4.2.3, and 4.2.4 respectively), and
3. modern analogs, where fresh peat is currently being formed.

This analysis proves the material used by Humatech has been formed by the same geologic drivers as the material in the analogous cases, and is, therefore, aged peat, and not lignite, Leonardite, nor coal. It is important to note that the material referred to as aged peat is not confined to one location. The geologic processes required to form aged peat occur throughout the world and throughout geologic time. Thus, the important point is not the geographic location of a specific aged peat formation, rather it is the geologic make up of the site and the geologic processes that lead to the formation of aged peat.

## 4.1 Sequence Stratigraphy Drivers

The following sections describe the driving components of sequence stratigraphy.

[5] Geology and Coal Resources of the Upper Cretaceous Fruitland Formation, San Juan Basin, New Mexico and Colorado, James E. Fassett, U.S. Geological Survey Professional Paper 1625-B, page Q3.

[6] Ibid., Fassett, page Q7.

[7] Ibid., Fassett, page Q18.

[8] Sequence Stratigraphy of Foreland Basin Deposits, AAPG Memoir 64, Chapter 4, Controls on Sequence Stacking and Fluvial to Shall-Marine Architecture in a Foreland Basin, Peter Schwans, page 1.

### 4.1.1 Tectonics

As geologic plates crash into each other, they change the height and depth of the respective plates, which changes where the beach is located. Similar tectonic activities occurs as the earth cools and plates shrink and sink, or as volcanoes occur, heating up the earth, expanding the earth, and raising the surface. Sea level is changed locally by these tectonic activities.

### 4.1.2 Eustasy

Sea level is more systematically changed by the rise and fall tied to the coming and going of ice ages. During an ice age the water is piled upon the poles as larger ice caps. During times of global warming the ice caps melt and sea levels raise. Typically these eustatic cycles are on the order of 200 meters (660 feet). The larger sea level changes are tied to variations in the eccentricity, axial tilt, and precession of the Earth's orbit and are known as Milankovitch cycles. The Earth's axis completes one full cycle of precession about every 26,000 years. The elliptical orbit rotates slower, with a combined effect of 21,000 years between astronomical seasons.

### 4.1.3 Sediment Supply

Sediment supply is tied to rainfall and erosion, which is tied to both tectonics and eustasy, or eustatic cycles, as well as frost, wind, rainfall, and water flow. When sea levels are low, because there is a buildup of water in glaciers, rivers will cut deep and way back from the shoreline and large amounts of sediment will be deposited offshore, including reworked glacial till. During these ice ages there is not as much vegetation and thus not as much peat being deposited as when times are warmer and the sea level is at it's maximum height.

### 4.1.4 Other Sea Level Drivers

The earth has other processes which impact these three sedimentation drivers, including salt, growth faults, and gas hydrates.

#### 4.1.4.1 Salts

When geologic plate spreading centers create a rift basin, like the Dead Sea or the Great Basin, there are are large salt water lakes created, like the Dead Sea and The Great Salt Lake. Rainwater leaches salts out of the sediments being eroded, these salts are transported to the isolated lakes with no drainage, and the evaporated salts can become very thick. As geologic cycles continue, these salts are covered with sediments, and as the sediments put the salt layer under pressure the salt turns to more fluid and moves to create salt pillows and salt domes. These salt structures occur relatively fast in the geologic time record, and can impact sea level locally.

#### 4.1.4.2 Growth Faults

As sedimentary layers are laid down, there are intervals which have high organic content. These occur when the sea are at their highest levels. These intervals of rock are known as Highstand Systems Tracts, and as they are buried by other sediments being deposited upon them, they become glide planes. In the Gulf of Mexico and other siliciclastic basins around the world, normal faults become growth faults, and these growth faults end sliding down these organic rich glide planes. As large sections of the coast line slip into the sea it changes the sea level locally.

#### 4.1.4.3 Gas Hydrates

As sediments are buried with new sediments being deposited on top of them, the sediments are put under pressure and the temperatures increase. Under the right temperatures and pressures the organic material in the sediments are cooked, like in a refinery, chemically cracked, and karogens become hydrocarbons. When a hydrocarbon molecule is created its goal is to get to the surface. This movement is driven by gravity because the hydrocarbon molecules are lighter than water or sediments. If the hydrocarbon molecules reach the surface in a polar area, or in water deeper than 600 feet, they freeze and create gas hydrates. Gas hydrates have a hydrocarbon molecule caged in water molecule ice. It is estimated 90% of the known hydrocarbons on earth are stored as gas hydrates. During ice ages, when the sea level falls, these hydrates melt, putting greenhouse gases into the atmosphere, which warms up the atmosphere, decreasing the size of the ice caps, and raising the sea level.

## 4.2 Application of Sequence Stratigraphy

The sea level drivers described in the previous section combine to create regular repeating cycles which define how the earth grows stratigraphically. In applying the principles of sequence stratigraphy to describe the formation of aged peat, there are two important points to keep in mind. First, there are regular sea level cycles which drive depositional processes. Second, these same depositional processes occur all across the earth and all throughout geologic time. This means we can take geological information, such as outcrop, well log, and seismic examples (see Appendix for definitions), from one place on the planet, and use these data as an analog describing what happened at other geologic times and at other places on the earth.

By understanding the geologic forces at work at one site where aged peat is deposited, we can apply sequence stratigraphy to identify other aged peat deposits.

For example, the deposition of the Fruitland Formation in the San Juan Basin, and the Blackhawk Formation in the Book Cliffs of Eastern Utah (Sections 4.2.3 and 4.3.4 respectively) are well documented and clearly include aged peat deposits. None of these deposits have been described as lignite in the literature. The depositional processes which occurred anciently in these two regions are consistent with modern areas of peat deposition (see Sections 3.2 and 3.3). Thus, knowing how the deposition process took place, and that the material deposited in these two areas was originally peat, sequence stratigraphy concepts help geologically prove that the material from Humatech's mine is indeed aged peat. It is important to note that in studying various aged peat analogs, it is not the geographic location that is important, rather it is the geological make up of the site and the processes which led to the formation of aged peat.

### 4.2.1 Application of Sequence Stratigraphy: General Case

This section uses outcrop, log, and seismic data to describe the deposition processes tied to the formation of aged peat, analogous to the area mined by Humatech.

Figure 6 shows an outcrop, similar to the outcrop being mined by Humatech, as well as a well log, and a seismic section, through similar geology. The outcrop, log, and seismic data each have an interpretation of the sea level cycles and resulting stratigraphic intervals drawn on them.[9]

The bottom outcrop, log, and seismic section show a sequence boundary, which is an unconformity occurring as the sea level reaches its minimum and starts to rise. Going up, the next outcrop, log, and seismic images show yellow colored basal transgressive sands, which are typically deep water sands transported from the beaches as submarine fans. The next blue interval is called a transgressive systems tract, are the sediments deposited as sea level continues to rise, and include the basal transgressive sands. When sea level reaches it's maximum level it creates the maximum flooding plane, or the green boundary interpretation drawn on the third down outcrop photo, well log, and seismic section. The green intervals on the next set of outcrop, log, and seismic images up show the sediments deposited during two geologic times when the sea level was at it's highest, which interval of sediments is called the Highstand Systems Tract. Highstand Systems Tracts are when the large peat bogs have been

[9] Personal communication with Ward Abbott, retired Chief Seismic Stratigrapher Shell Oil and later Chief Seismic Stratigrapher at Occidental Petroleum, 2008.

deposited worldwide and throughout geologic time.

The top outcrop, log, and seismic interpretations show deltaic deposition, which occurs as the sea level starts to fall and as sediments, including peat bogs, are eroded, washed out to sea, and redeposited. The important point is that there are regular sea level cycles which drive depositional processes. This depositional process describes formation of the rocks at the area mined by Humatech. One of the interesting characteristics of the area Humatech is mining is that there was little erosion of the peat bogs before limestone reefs started to grow on top of the peat.

### 4.2.2 Application of Sequence Stratigraphy: Barracuda field in the Campos Basin offshore Brazil

The Barracuda Field in the Campos Basin offshore Brazil offers another depositional analog to the aged peat mined by Humatech. In this example reflection seismic analysis is used to illustrate the analogy. Geoscientists have learned to model these stratigraphic depositional processes based on anticipated and historical tectonic activity, eustasy, and sediment supply. In addition, these geologic models can be turned into reflection seismic models as shown in Figure 7. [10] Reflection seismic analysis is an imaging technology widely used in hydrocarbon exploration. The detailed subsurface images created with seismic data provided a basis for developing sequence stratigraphy concepts. Seismic data, or higher frequency ground penetrating radar, are used to image coal fields and aged peat deposits like Humatech is mining. The image produced from reflection seismic analysis is like a knife slice in the subsurface of the earth. Trenching and well control are often sufficient geologic control for shallow mining operations.

Figure 8 is a seismic image of the Barracuda Field in the Campos Basin offshore Brazil.[11] This example was selected because the reflectors marked “reservoir interval” are very similar to the anticipated seismic reflections at the current Humatech mine. The reason this image is similar to the Humatech mine is the thinning seismic attribute shows a boundary at a maximum flooding surface (white dashes showing erosion and deposition at maximum sea level). In this figure, the thinning seismic attribute shows a boundary at a maximum flooding surface (white dashes), and this boundary is where peat and coal deposits occur vertically in a section. Since the maximum flooding surface is exposed to the atmosphere for long periods of time,

[10] Geometric attributes for seismic stratigraphic interpretation, Tomas van Hoek, Stephanie Gesbert, and Jim Pickens, The Leading Edge, September 2010, page 1056.

[11] Ibid., Hoek, et. al., page 1057.

unconformities occur at these layers, as shown in the unconformity attribute, the bottom of the three images in Figure 8.

#### 4.2.3 Application of Sequence Stratigraphy: The Fruitland Formation in The San Juan Basin

##### 4.2.3.1 Geologic and Stratigraphic Description

The Fruitland Formation coal beds were deposited in backshore swamps on top of Pictured Cliffs Sandstone shoreface deposits during the same general geologic time frame. While coal beds are generally not continuous for more than a few miles, in some areas coal zones are continuous for tens of miles. Coal beds range from paper thin to more than 50 feet thick. Fruitland net-coal thicknesses range from 1.2 feet to more than 90 feet. The thinner coal bands probably represent fluvial channel systems that cut through the backshore peat swamps on their journey to the sea.[12]

The Fruitland Formation in the San Juan Basin is a prolific coalbed-methane producing unit. The thick accumulation of Fruitland peats landward of coeval, northwest-trending shoreface and wave-dominated deltaic complexes in the Pictured Cliffs Sandstone. These trends of greatest net coal thickness occur landward of areas of significant intertonguing of the Fruitland Formation and Pictured Cliff Sandstone, recording multiple cycles of transgression and regression. During the Late Cretaceous (late Campanian and early Maastrichtian), the region of the present San Juan Basin was on the western margin of the the Western Interior seaway, eastward of the Sevier thrust belt.[13]

> The coastline migrated to the northeast, depositing a vertical succession of shelf through coal-bearing continental sediments. The Pictured Cliffs Sandstone is a coastal facies that was deposited as the late Cretaceous shoreline prograded northeastward into the Western Interior seaway. Pictured Cliffs Sandstones are the depositional platforms upon which Fruitland peat accumulated, and ultimately, Pictured Cliff shoreline sandstones bound coal seams in the basinward direction. Progradation of the Pictured Cliffs shoreline, dependent on complex interactions of sediment supply, basin subsidence, and eustasy, was intermittent and

[12] Ibid., Fassett, page Q1.

[13] Geologic controls on transgressive-regressive cycles in the upper Pictured Cliffs Sandstone and coal geometry in the lower Fruitland Formation, northern San Juan Basin, New Mexico and Colorado, William A. Ambrose and Walter B. Ayers Jr., AAPG Bulletin, volume 91, number 8, August 2007, page 1101.

was punctuated by shoreline stillstands.[14]

Although the Late Cretaceous was a period of peak greenhouse climate, glacieustasy, associated with small ($<10^6$-km$^3$), ephemeral ice sheets in Antarctica, could have provided the mechanism for the origin of transgressive-regressive cycles on a global scale. Moreover, 400-k.y. cyclicity related to the Milankovitch long eccentricity band could possibly account for major offlapping cycles in the Luis Shale-Fruitland succession. However, the origin of the high-frequency, transgressive-regressive cycles in the Luis Shale-Fruitland interval may also reflect intermittent tectonic activity.[15]

#### 4.2.3.2 Analogous Characteristics to Humatech's Aged Peat

Figure 9 presents a depositional model for the Fruitland Formation.[16] The widespread deposition of these peat deposits in the Fruitland formation is shown by the observation that Holocene peat is compacted to 20% of its original thickness within 11 meters (36 feet) of burial.[17]

Where peat has been transformed to lignite, there is typically no peat left. Where there is coal, there is typically no lignite. Where there is aged peat and coal together, it means there has not been enough burial pressure or thermal maturation to change all of the rocks. There are two coal layers, separated by a clay layer, just underneath the aged peat Humatech is mining.

The rank of coal beds in the Fruitland Formation in the central part of the San Juan Basin, where major gas production occurs, increases to the northeast and ranges from high-volatile bituminous coal to medium-volatile bituminous coal.[18]The coals at the Humatech mine are too soft to be anthracite coal, and too hard to be subbituminous coal. The presence of both aged peat and coal at Humatech's mine indicates a lack of lignite. While the peat layer at Humatech's mine has patterns from the wood, there are no identified fibers, meaning is a very old peat layer (see Section 3.1). Again no lignite has been identified in the San Juan Basin. This is certainly related to the burial history and thermal maturation of rocks in the basin.

[14]Ibid., Ambrose and Ayers, page 1102.
[15]Ibid., Ambrose and Ayers, page 1107.
[16]Ibid., Ambrose and Ayers, page 1106.
[17]Depositional and diagenetic controls on reservoir attributes within a fluvial outcrop analog: Upper Triassic Sonsela member of the Chinle Formation, Petrified Forest National Park, Arizona, Aislyn M. Trendell, Stacy C. Atchley, and Lee C. Nordt, AAPG Bulletin, volume 96, number 4, April 2012, page 698.
[18]Characterization of coal-derived hydrocarbons and source-rock potential of coal beds, San Juan Basin, New Mexico and Colorado, U.S.A., Dudley D. Rice, Jerry L. Clayton, Mark J. Pawlewicz, International Journal of Coal Geology, volume 13, issues 1-4, July 1989, page 597.

### 4.2.4 Application of Sequence Stratigraphy: Blackhawk Formation in the Book Cliffs of Eastern Utah

The Blackhawk Formation in the Book Cliffs of Eastern Utah is one of many similar geologic formations occurring throughout the four-corners area, including the Cretaceous (same geologic age and same depositional basin as the sediments being mined by Humatech for dried age peat).

#### 4.2.4.1 Geologic and Stratigraphic Description

This Cretaceous Blackhawk Formation of the Mesaverde Group in eastern Utah comprises coal-bearing coastal-plane and wave dominated shallow-marine strata that intertongue with the offshore, marine Mancos Shale further to the east.[19]

> The humate-rich bed being mined (at the Clod Buster Mine in section 9, township 17 N., R. 1 W., along the old highway between Cuba and La Ventana in New Mexico) is near the top of the Upper Cretaceous Menefee Formation, associated with the persistent coal zone at the stratigraphic position of the San Miguel (Padilla) coal mines about 1.5 miles to the north. The humate-rich bed is similar lithologically to the brown "underclay," rich in plant fragments, that underlies most San Juan Basin coals.[20]

#### 4.2.4.2 Analogous Characteristics to Humatech's Aged Peat

A key similarity between the deposition process at the Blackhawk Formation and the area currently mined by Humatech is a similarity in the accommodation rate leading to the formation of aged peat found at both locations. As basins cool or as sea level rises there is additional vertical space for sedimentary fill, which is called the accommodation space. If eroded sediments or vegetation growth fills this space at approximately the same rate as the space becomes available, deposition is occurring at the accommodation rate. This is a key factor in the formation of thick peat bogs.

One of the key issues to be addressed in modern stratigraphic research is the correlation and integration of the terrestrial and shallow-marine records. Recognizing expressions of base-level change in terrestrial strata is inherently more difficult than in marine strata. An exception to this occurs because of the sensitivity of the original peat bodies to changes in depositional conditions. For peat to accumulate and be

[19] High Resolution sequence-stratigraphic correlation between shallow-marine and terrestrial strata: Examples from the Sunnyside Member of the Cretaceous Blackhawk Formation, Book Cliffs, eastern Utah, Ron Davis, John Howell, Ron Boyd, Stephen Flint, and Claus Diessel, AAPG Bulletin, volume 90, number 7, July 2006Ibid., Davis, et. al., page 1124.

[20] Humate Mining in Northwestern New Mexico, John W. Shomaker and William L. Hiss, New Mexico Geological Society Guidebook, 25th Field Conference, 1974, page 334.

reserved, the accommodation rate has to approximately balance the rate at which peat is produced. If the accommodation rate exceeds the rate of peat production, the mire is drowned and inundated with marine or lacustrine sediment. Conversely, if peat production outstrips the accommodation rate, the mire is exposed, oxidized, and reworked.[21]

The mires where plants grow, in back of the beaches, are known as peat bogs. These deposits form peat soils, which are very good farming soils. If the peat is the right thickness and has the right chemical composition it will turn into coal.

> High-frequency changes in the balance between accommodation and peat production in the peat window should result in changes in the nature of the coaly rocks that are deposited. ... Higher accommodation rates should give rise to coaly shales and shaly coals with inorganic mineral content in excess of 30%, as rapidly rising base level provides a mechanism for the transport of waterborne, detrital minerals into the mire. Lower accommodation rates should result in the formation of limnotelmatic and ombrotropic coal, with mineral content below 30 and 10%, respectively. Very low accommodation rates may give rise to inertinite-rich coal (>50% inertinite on a mineral free basis), in which mineral content is increased because of oxidation and burning of the peat. [22]

Just as at the Blackhawk Formation in Utah, high accommodation rates occurred when what is now aged peat was growing as vegetation where the Humatech San Juan Basin mine is located now. This is shown by the percent clay and shale in the aged peat present at both locations.

### 4.2.5 Application of Sequence Stratigraphy: Modern Analogs to Humatech's Aged Peat

A modern analog of these ancient swamps which became the aged peat layer mined by Humatech are the swamps between Lafayette and New Orleans, Louisiana. Other modern analogs for peat-forming environments in transgressive sequences include the Snuggedy swamp and Cape Romain in South Carolina. The organic / inorganic composition of these modern day swamps is similar to the composition of the ancient swamps that eventually became the aged peat currently mined by Humatech. These areas occur along an upper microtidal to lower mesotidal coastline where peat and marsh environments are being encroached by relative sea level rise. Areas in

[21]Ibid., Davis, et. al., page 1122.
[22]Ibid., Davis, et. al., page 1123.

Snuggedy Swamp exist where freshwater peat is currently under salt-marsh vegetation or lagoonal clay and silt, corresponding to an early deepening and submergence pretransgressive phase in the backbarrier.[23]

#### 4.2.6 Application of Sequence Stratigraphy: the Formation of Aged Peat at Humatech's Mine

The chemical, physical, and stratigraphic differences between aged peat and lignite have been discussed earlier in this document, in addition to geological formations equivalent to sediments at Humatech's mine, as shown using sequence stratigraphy. This section uses these concepts to describe the formation of the aged peat mined by Humatech.

Marine regression occurs when the submerged seafloor is exposed above the sea level. Marine transgression is the opposite and occurs when flooding from the sea covers previously exposed land. Figure 10[24] shows a marine regression model of how beach sands, peat marshes, and lacustrine river deposits are being deposited further and further out to sea on top of seafloor deposits as time passes. Sequence stratigraphy demonstrates these processes are driven by combinations of tectonics, eustatics, and sediment supply.

Figure 10 illustrates how peat layers are deposited near the coast in swamps. As the sea level starts to reach it's maximum level, at the the beginning of the Highstand Systems Tract, the swamps can be very prolific and create thick peat bogs which become coal. As the maximum flooding surface is reached, inter coastal waterways can inundate the plants and leave layers of clay. Then as the sea level starts to drop at the end of the Highstand Systems Tract, the swamps can again become very prolific and create thick peat bogs which become another coal layer. As the sea level drops more, towards the lowstand systems tract, there is a change in the plants in the swamps, particularly on a peneplain where the swamps can go many miles inland from the coast. The changes in vegetation changes the type of peat deposited. The higher the acidity and lower the pH of these deposits, along with the depositional thermal and pressure history, determines whether the peat will turn to coal or remain a peat. As the sea level drops a bit more, say 10-30 meters, coral reefs form and create limestone layers. It is reasonable to assume the horizontal rigidity of a limestone cover protects underlying peat bogs from the temperatures and pressures of deposition, so these layers retain peat characteristics.

[23] Ibid., Ambrose and Ayers, page 1112.
[24] Ibid., Fassett, page Q35.

This vertical sequence of:

- Limestone over
- Peat over
- Coal over
- Clay over
- Coal

summarizes the geology at the current Humatech mining operation.

Figure 11 is a similar model showing the growth of coals in the non-marine / marginal marine setting.[25] This figure is a more detailed version of Figure 10, showing how multiple layers of coal, as occur at the Humatech mine, grow with small variations in sea level. Sequence boundaries are tied to maximum and minimum sea levels, while parasequence boundaries are tied to local sea level changes which can be impacted by tectonic uplift at plate boundaries, sediment supply, tidal heights, and other factors. As described in the definitions below, parasequences are a conformable succession of genetically related beds bounded by flooding surfaces, while a sequence is a conformable succession of genetically related beds bounded by maximum and minimum sea level flooding and erosional surfaces.

> The coal seam overlying the basal section of the lower Fruitland tongue records development of bayfill or lacustrine-fill deposits overlain by emergent peat swamp deposits associated with a major regression or equivalent lowstand cycle. ... The introduction of these lower Fruitland peats is inferred to reflect emergent conditions, recording the onset of terrestrialization caused by regression and decreasing accommodation in the lower coastal plain. ... Peat accumulation is favored after the relative sea level rise has decelerated to a rate comparable to that of the growth rate of peat-forming plants. The beginning of peat formation is part of the terrestrialization process that corresponds to decreasing accommodation, which facilitates paludification and peat accumulation, thereby leading to regressive coals.[26]
>
> The Pictured Cliffs shoreline may have been stabilized by aggrading peat swamps in raised mires. Because peat accumulation may keep pace with sea level rise, the development of raised mires may reduce the extent of marine transgression and stabilize the shoreline. Raised mires,

[25] Sequence Stratigraphy of Foreland Basin Deposits, AAPG Memoir 64, Chapter 3, Stratigraphy and Facies Architecture of Parasequences with Examples from the Spring Canyon Member, Blackhawk Formation, Utah, Diane L. Kamola and John C. Van Wagoner, page 45.

[26] Ibid., Ambrose and Ayers, page 1112.

> protected from clastic influx, typically result in low-ash peats (coals) and are present closely landward of many vertically stacked parasequences in Cretaceous strata in the Western Interior suggest that Fruitland coals are analogous to high-ash peats of the Dismal swamp in the southeastern United States.[27]

This development of raised mires can impact the normal coastal onlap curves and create parasequences, as shown in Figure 12.[28] These parasequences can leave large areas of the peneplain surface inundated in mires, as shown in Figure 13.[29] These large top set accumulation volumes become the basis for unique humate mining opportunities.

## 5 Results

The term "aged peat" is geologically appropriate for the material Humatech is mining. The material was formed in the Cretaceous, shown above to be between 65 and 98 million years ago.

A key geologic question behind the request for this report is whether this material is a peat or a lignite. No references were found in the literature of lignites being found in New Mexico. Several of the above references refer to New Mexico coals as bituminous coals. No references were found showing bituminous coals and lignite occurring together. There are significant differences between aged peat and lignite, which have been highlighted in this report. These differences includes the fact aged peat was formed in an environment where the accommodation rate slightly exceeds the peat production rate resulting in some clay deposition, high acidity, a soft and crumbly material, and no combustibility. These geological characteristics describe the material being mined by Humatech.

The material Humatech is mining is different from coal. It does not burn. Like other northwestern New Mexico deposits, there are concentrations of humic acids, and their salts (which are properly termed humates), expressed in terms of humic acid, which have reached 70 percent by weight in some samples collected from the

[27] Ibid., Ambrose and Ayers, page 1117.

[28] Sequence Stratigraphy of Foreland Basin Deposits, AAPG Memoir 64, Chapter 3, Stratigraphy and Facies Architecture of Parasequences with Examples from the Spring Canyon Member, Blackhawk Formation, Utah, Diane L. Kamola and John C. Van Wagoner, (based on Figure 1, page 64, in Vail et al., 1977), page 31.

[29] Sequence Stratigraphy of Foreland Basin Deposits, AAPG Memoir 64, Chapter 1, Topset Play Types and Their Controls, N.J. Milton and G.T. Bertram page 1.

Upper Cretaceous coal-bearing sediments.[30]

There is an associated lignite, named "Leonardite," which has been given to a similar material high in humic-acid content and is found in North Dakota and the adjacent or nearby States of South Dakota, Montana, Colorado, and Wyoming. There is no mention of Leonardite being found in New Mexico. In northwestern New Mexico the Cretaceous Fruitland Formation and Mesaverde Group have rich zones of coal and carbonaceous material.[31] Specifically:

> The term used in the literature for oxidized lignites is Leonardite. Leonardite refers to a particularly geologic deposit of oxidized lignite in North Dakota, but has often been misapplied to lignite deposits found elsewhere.[32]

## 6 Conclusion

“Aged Peat” is an appropriate name, geologically, for the material that Humatech is mining. The sediments have had between 65 and 136 million years to dry out and be aged. The background section defines peat, how it can eventually turn into lignite or eventually coal, and how when it does make this transformation, it looses volatile substances, including humic acids. Since there are extensive humic acids in the material Humatech is mining, it follows this material has neither aged nor been cooked sufficiently to form lignite, Leonardite, nor coal. Nor is this material a fresh peat as the organic material in aged peat has completely decomposed to the point of where plant fibers are not recognizable. Again, the objective of this paper is to establish aged peat as a common and usual name, based on geology, for the product produced by Humatech.

This paper establishes peat layers are deposited near the coast in swamps, and that these peat layers can be directly related to sequence stratigraphy. In the Methods Section the process of creating sedimentary geology in layers was described. Details were presented on marine regression and transgression, with a brief discussion on tectonic, eustatic, sediment supply, and key sea level drivers. Sequence stratigraphy was reviewed and examples of outcrop, log, and seismic displays of geologic deposition, analogous to the Fruitland Formation deposition, were presented. Key geologic literature on the deposition of the Fruitland Formation in the San Juan Basin were

[30] Ibid., Shomaker and Hiss, page 333.

[31] Ibid., Shomaker and Hiss, page 333.

[32] Oxidized Lignites and Extracts from Oxidized Lignites in Agriculture, Michael Karr, May 2001, page 3.

reviewed, as well as seismic and seismic attribute analogs were reviewed. Sequence chronostratigraphy of the area where the Humatech mine is located was reviewed. A depositional model of the Pictured Cliffs and Fruitland Formation was presented showing the thick aged peat deposits might be the result of increased subsidence along a basin homocline, which compensated for marine transgression and resulted in thick peat deposits. Other Cretaceous outcrops, like the Book Cliffs, to the north-east of the Humatech mine, were reviewed, showing it is relatively common to have high frequency changes in the balance between accommodation and peat production, i.e. parasequences, which results in stacked coal, clay, coal, clay, aged peat, and limestone deposits, like at the Humatech mine. The peat deposition appears to be related to top set accommodation. The fact that these peat deposits have not matured to be lignite nor coal was demonstrated from the literature review and from the fact that the sediments being mined do notpeat deposits have not matured catch on fire when a match is held to them for an extended period of time.

Again, the term "Aged Peat" is an appropriate name, geologically, for the material Humatech is mining.

# 7 Appendix 1. Vitae and Definitions

## 7.1 Author's Professional Vitae

As an experienced geoscientist in the international petroleum industry since 1970, with proven success in using, creating, and building new tools and processes for the hydrocarbon exploration industry, I consult on geologic and geophysical projects which are of interest to me. In 2008 I was one of seven founders of Dynamic Measurement, LLC (DML). I also formed a consulting company (W3D) and an exploration company (DRC) to utilize industry and proprietary tools and processes to explore for, develop, and produce hydrocarbons. As the initial founder of Landmark Graphics, I created a university program which placed advanced interactive interpretation systems in many universities worldwide to support research and teaching. I designed the functionality of Landmark Graphics seismic interpretation software. The Landmark team created worldwide markets, with training courses and with technical support. As the only experienced end user at LGC for the first several years of the company, I participated in regional and detailed interpretation projects in The United States, Canada, China, Australia, Indonesia, and the North Sea with most of the major oil and gas exploration companies. I established Landmark's University Program, helping students and professors develop new technologies from Australia to Holland. I have been fascinated with geology since fifth grade when I found a rock by a coal mine which shows five sea level transgressions and regressions, and which is directly related to the question of whether Humatech is mining and distributing peat or lignite.

## 7.2 Definitions

The following definitions provide the basis for this report.

### 7.2.1 Accommodation Rate

Space in which sediments can be deposited, usually the space between sea level and the sea floor is know as the accommodation space.[33] The accommodation rate is being matched when deposition of eroded material or growth of vegetation fills this space at about the same rate as the vertical space becomes available.

[33] Encyclopedic Dictionary of Applied Geophysics, Robert E. Sheriff, Fourth Edition, 2002, Society of Exploration Geophysicists, Tulsa, Oklahoma, page 2.

#### 7.2.2 Aged

Phys. Geog. old; approaching the state of peneplain[34], an area reduced almost to a plain by erosion.[35]

#### 7.2.3 Coal

The natural, rock like, brown to black derivative of forest-type plant material, usually accumulated in peat beds and progressively compressed and indurated until it is finally altered into graphite or graphite-like material.[36]

#### 7.2.4 Cretaceous

The latest system of rocks or period of the Mesozoic Era, between 136 and 65 million years ago.[37]

#### 7.2.5 Dried

pt. and pt. of dry[38], 1. free from moisture or excess moisture; not moist; not wet; 5. not now containing or yielding water or other liquid.[39]

#### 7.2.6 Eustasy

Worldwide sea level regimes and their changes. The interplay of eustatic changes with isostatic subsidence and tectonic (thermal) uplift produces relative sea-level changes. Relative sea level and sediment supply produce sequence boundaries.[40]

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[34] The Random House Dictionary of the English Language, Second Edition, 1987, Random House, Inc., New York, page 37.

[35] Ibid., Random House, page 1433.

[36] McGraw-Hill Dictionary of Scientific and Technical Terms, Fifth Edition, 1994, McGraw-Hill, Inc., New York, page 392.

[37] Ibid., McGraw-Hill, page 479.

[38] Ibid., Random House, page 597.

[39] Ibid., Random House, page 601.

[40] Ibid., Sheriff, page 125.

### 7.2.7 Highstand Systems Tract

The upper systems tract within a sequence, characterized by aggradation followed by progradation. Involves deposition on a shelf during the late part of a cycle of eustatic rise, stillstand, and the early part of an eustatic fall.[41]

### 7.2.8 Leonardite

The name given to high humic-acid content material associated with lignite in North Dakota, South Dakota, Montana, Colorado, and Wyoming.[42]

### 7.2.9 Lignite

Coal of relatively recent origin, intermediate between peat and bituminous coal. Also known as brown coal; earth coal.[43]

### 7.2.10 Parasequence

A relatively conformable succession of genetically related beds bounded by flooding surfaces. One results from a small-scale relative sea-level rise and stillstand with little intervening fall, often with cyclicity of 100-150, 40, or 20 thousand years. A parasequence is terminated by another rise of sea level.[44]

### 7.2.11 Peat

A dark-brown or black residuum produced by the partial decomposition and disintegration of mosses, sedges, trees, and other plants that grow in marshes and other wet places.[45]

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[41] Ibid., Sheriff, page 176.

[42] Humate Mining in Northwestern New Mexico, John W. Shomaker and William L. Hiss, New Mexico Geological Society Guidebook, 25th Field Conference, Ghost Ranch, 1974, page 333.

[43] Ibid., McGraw-Hill, page 1139.

[44] Ibid., Sheriff, page 257.

[45] Ibid., McGraw-Hill, page 1461.

### 7.2.12 Peat Bog

A bog in which peat has formed under conditions of acidity. Also known as peat bed; peat moor.[46]

### 7.2.13 Peat Soil

Soil containing a large amount of peat; it is rich in humus and gives an acid reaction.[47]

### 7.2.14 Fruitland Formation

A Cretaceous formation in northwestern New Mexico with abundant zones rich in coal and carbonaceous material. Wherever the Mesaverde Group and Fruitland Formation are exposed there has been exploration for humate materials, including near Gallup, Crownpoint, Madrid, and Cuba-San Ysidro.[48]

### 7.2.15 Sequence Stratigraphy

The study of rock relationships within a chronostratigraphic framework of genetically related strata bounded by surfaces of erosion or non-deposition or their correlative conformities.[49]

[46] Ibid., McGraw-Hill, page 1461.
[47] Ibid., McGraw-Hill, page 1461.
[48] Ibid., Humate Mining, page 333-336.
[49] Ibid., Sheriff, page 314.

# 8 Appendix 2. Figures

## List of Figures

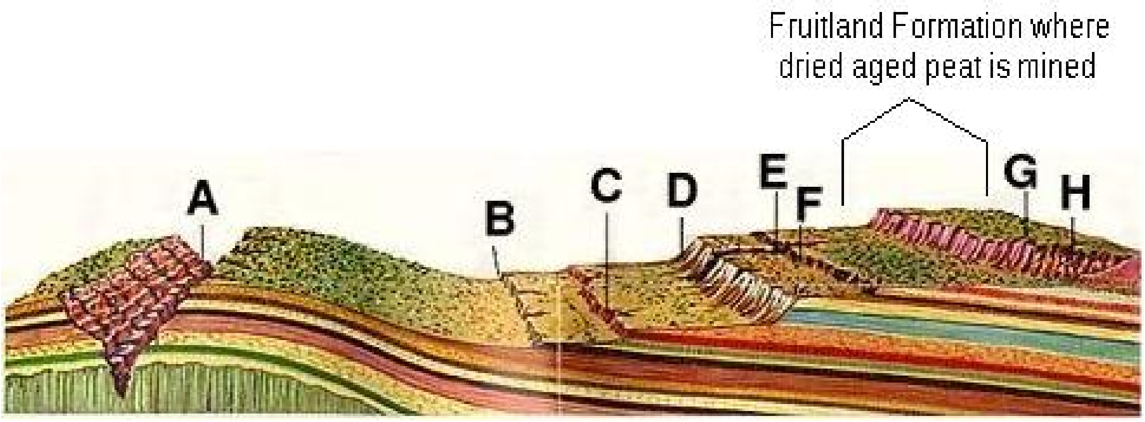



Figure 1: Grand staircase layer cake geology: (A) the Grand Canyon, (B) the Chocolate Cliffs, (C) the Vermilion Cliffs, (D) the White Cliffs, (E) Zion Canyon, (F) the Gray Cliffs, (G) the Pink Cliffs, and (H) Bryce Canyon. The Fruitland Formation, where aged peat is mined, is between the (F) Gray Cliffs and the (G) Pink Cliffs in geologic age.

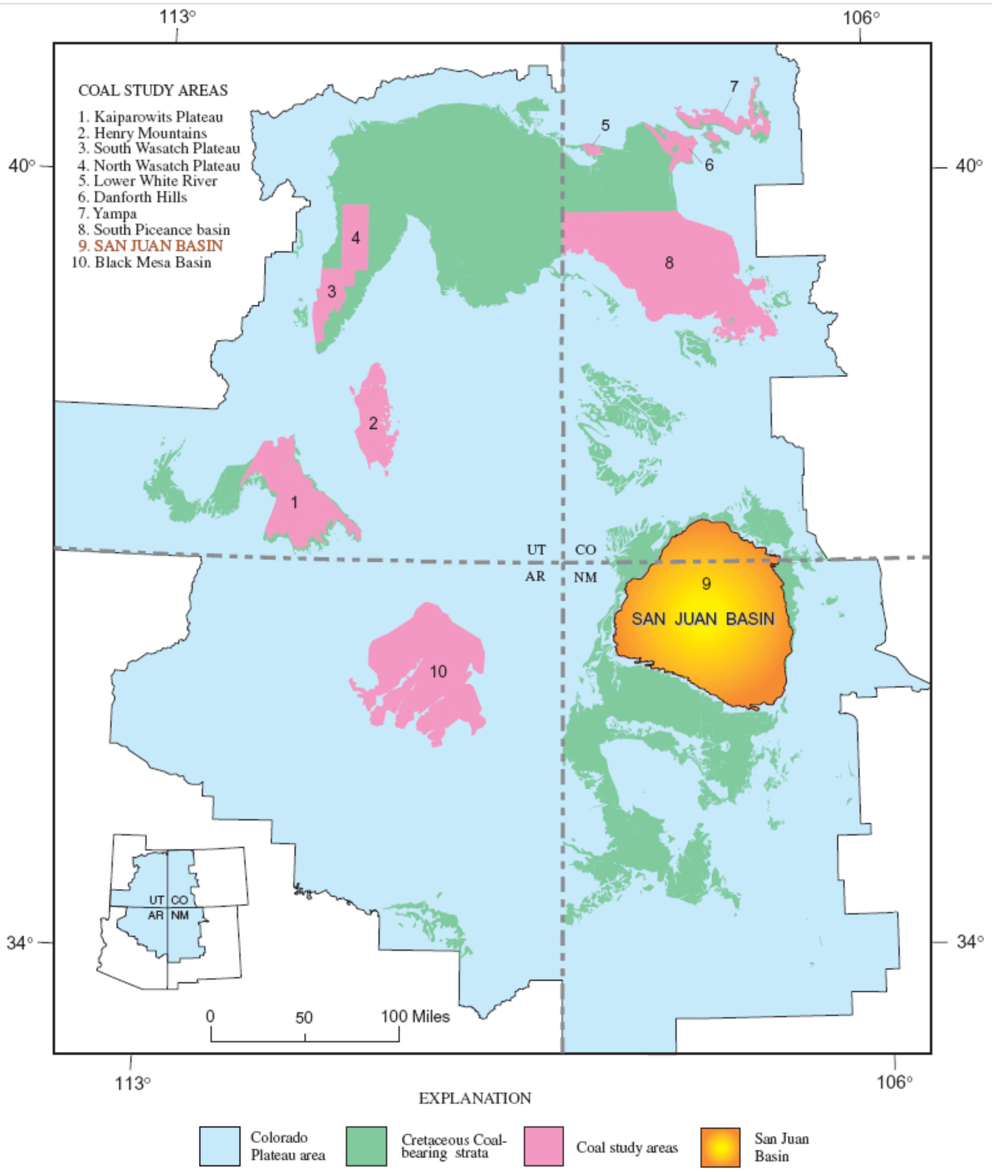



Figure 2: Example Area San Juan Basin, NM

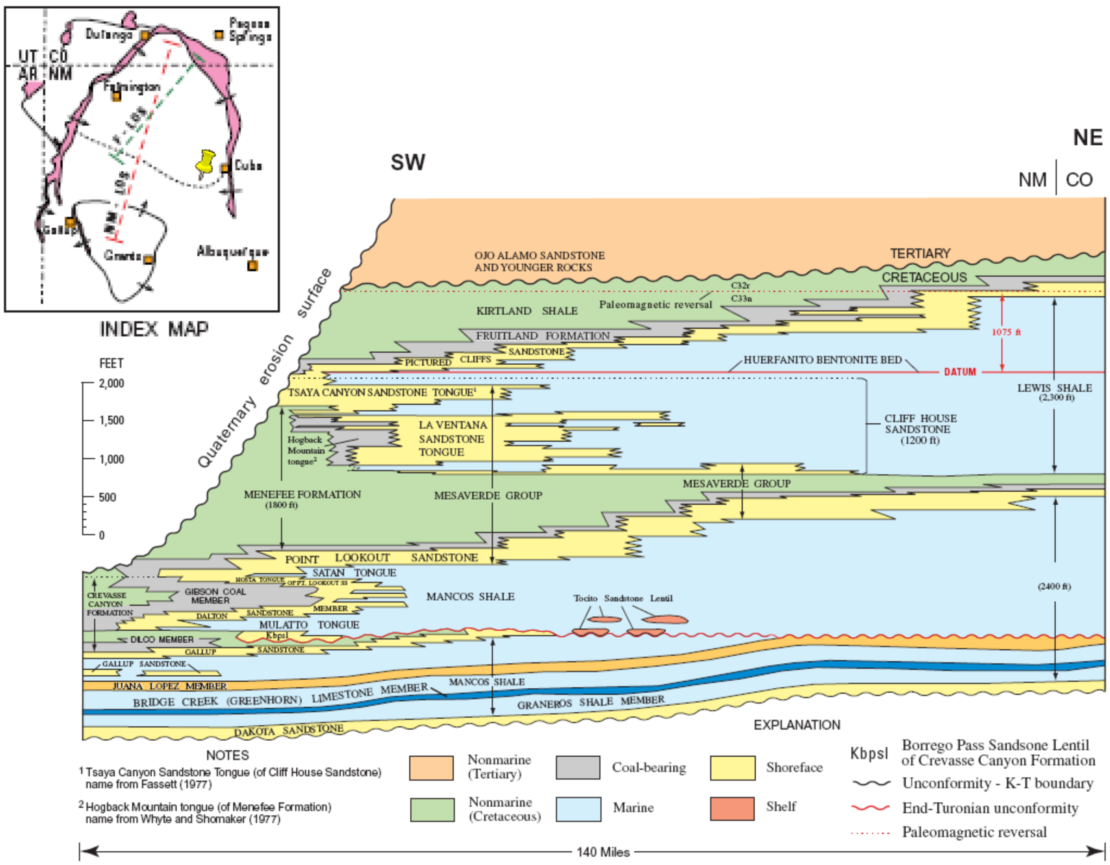



Figure 3: Cretaceous Stratigraphic Section of the Fruitland Formation. Yellow pin shows location of Humatech's mine.

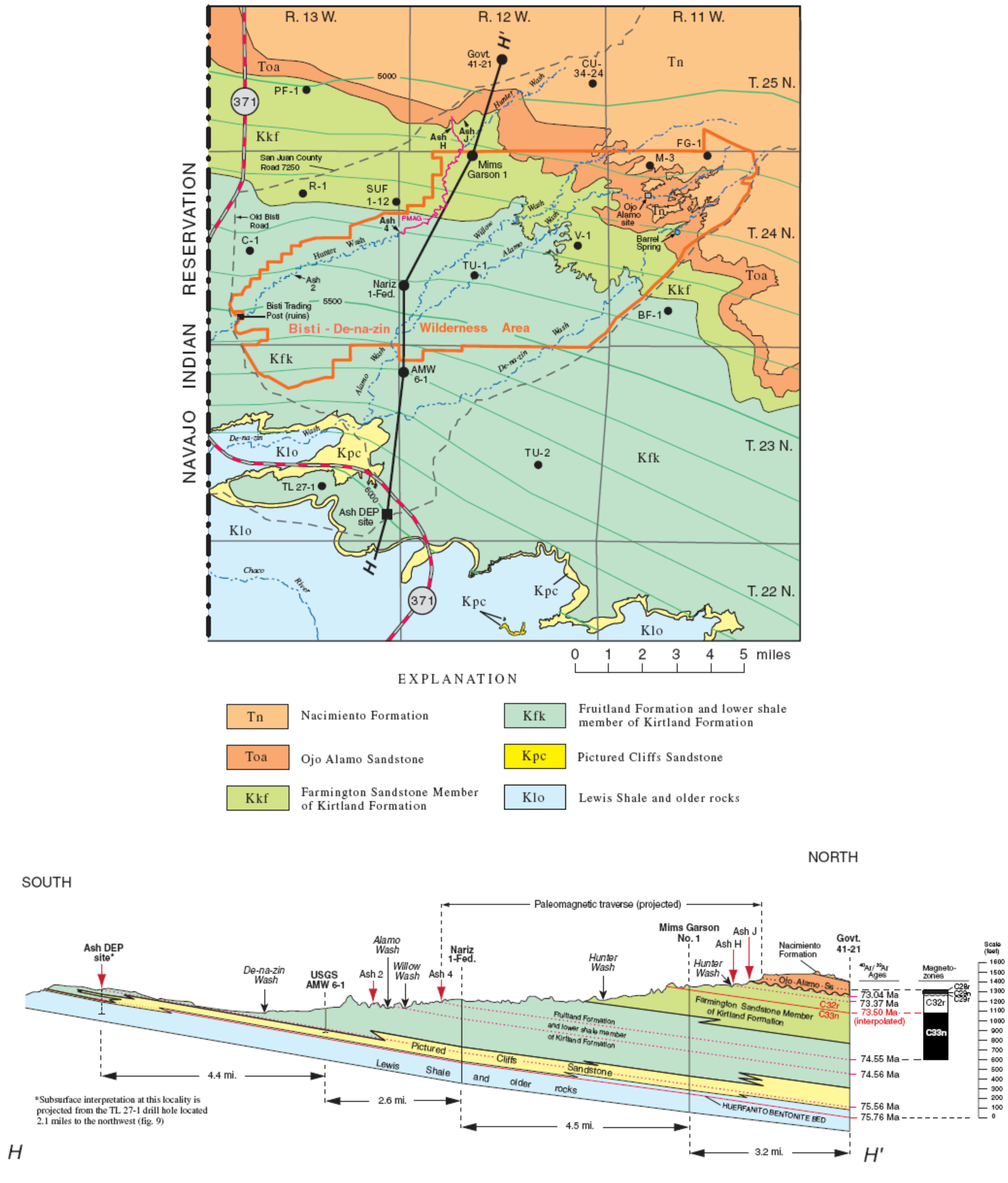



Figure 4: Fruitland Formation cross-section, which is a few miles northwest of Humatech's current mining operation

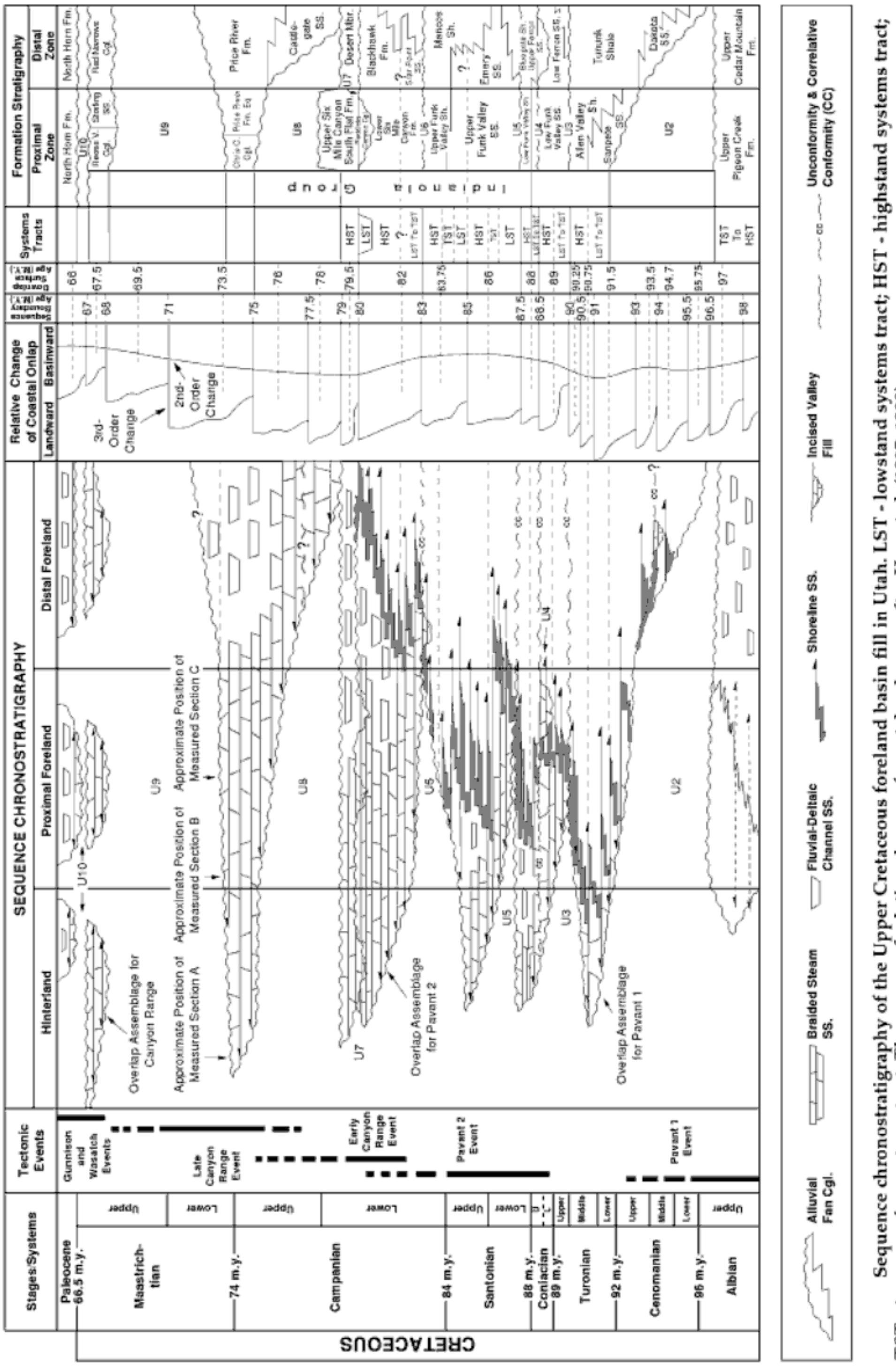



Figure 5: Cretaceous Sequence Stratigraphy

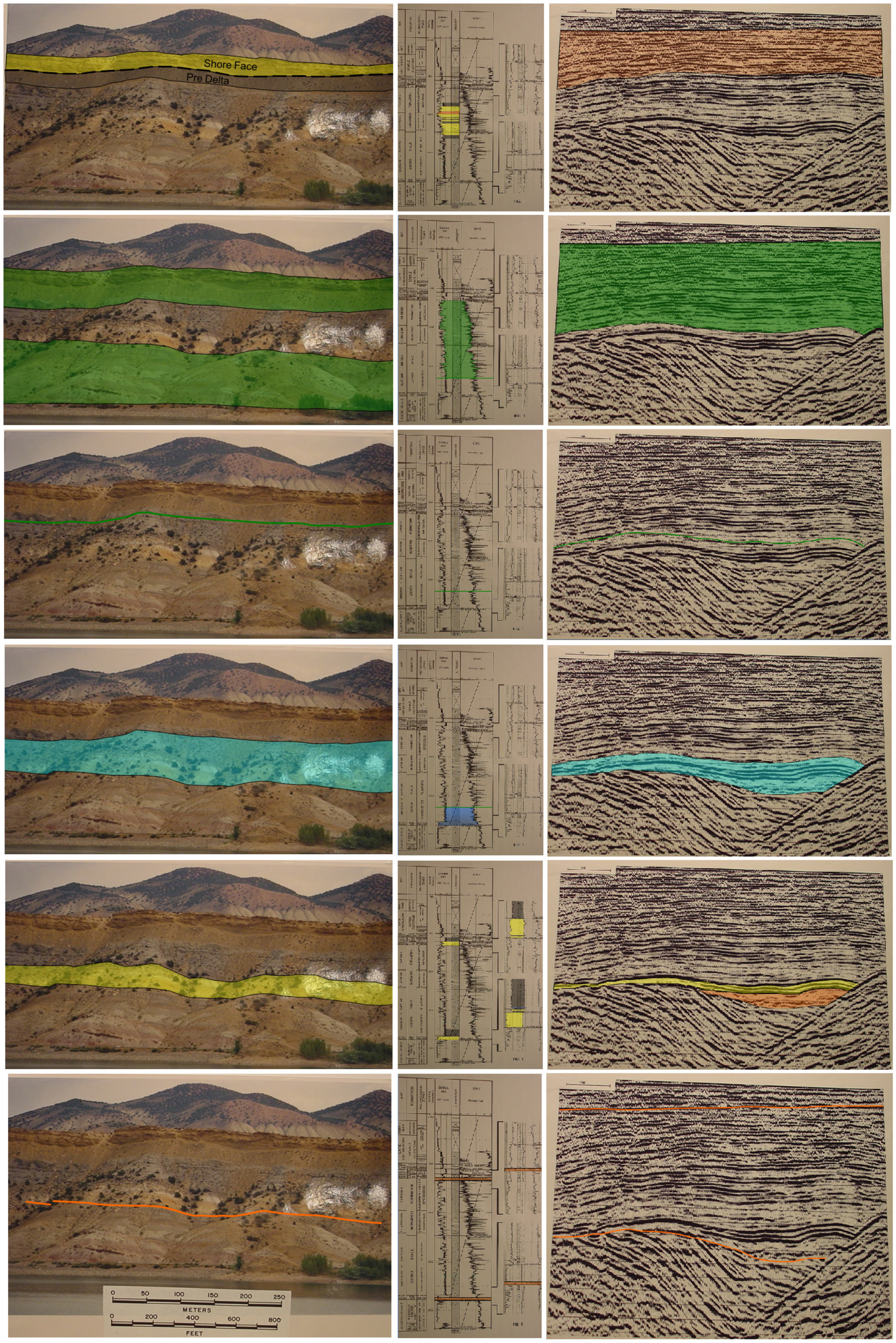
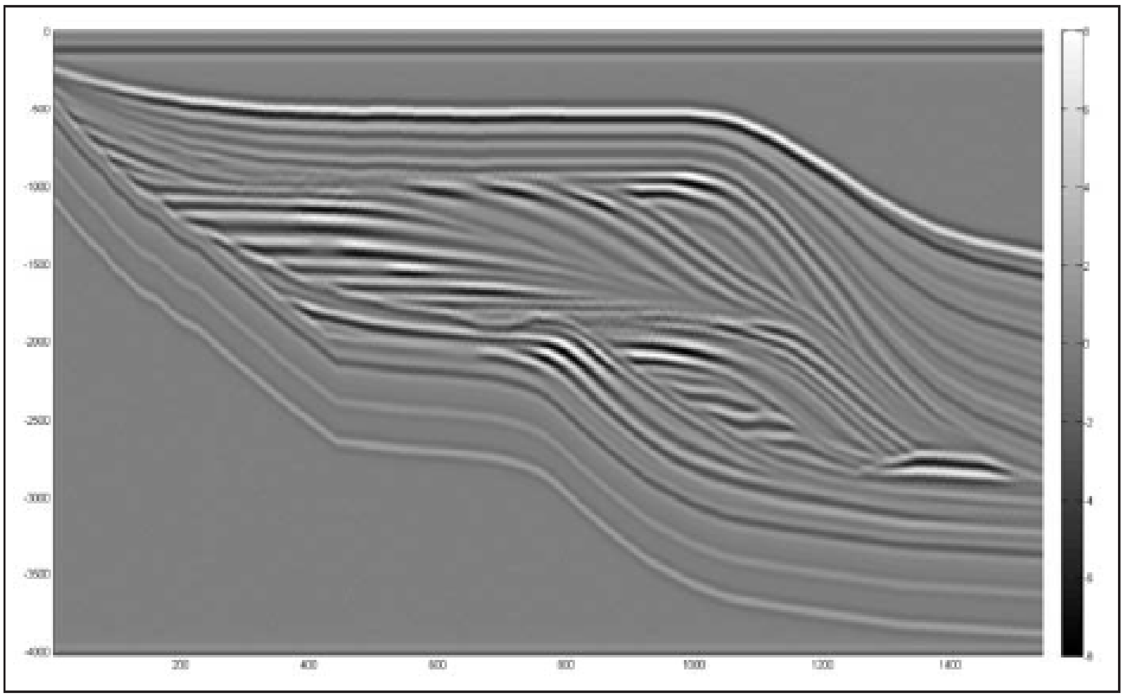
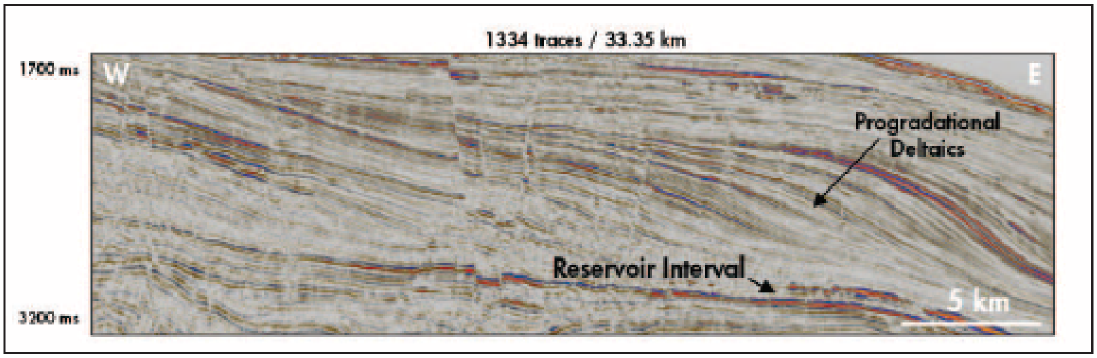



Figure 6: Sequence Stratigraphy on outcrop, log, and seismic data

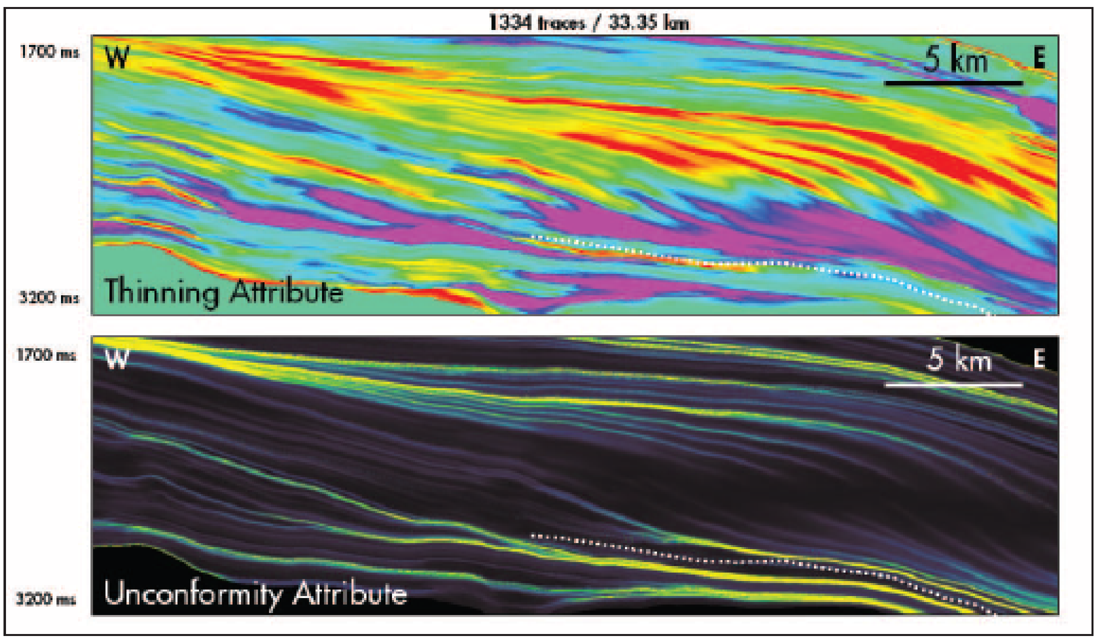



*Synthetic version of Vail's seminal systems tract schematic used to illustrate the geometric attributes and pseudo-Wheeler display. (After Vail, 1987.) Vertical axis = ms and horizontal axis = traces.*

Figure 7: Synthetic seismic systems tract schematic

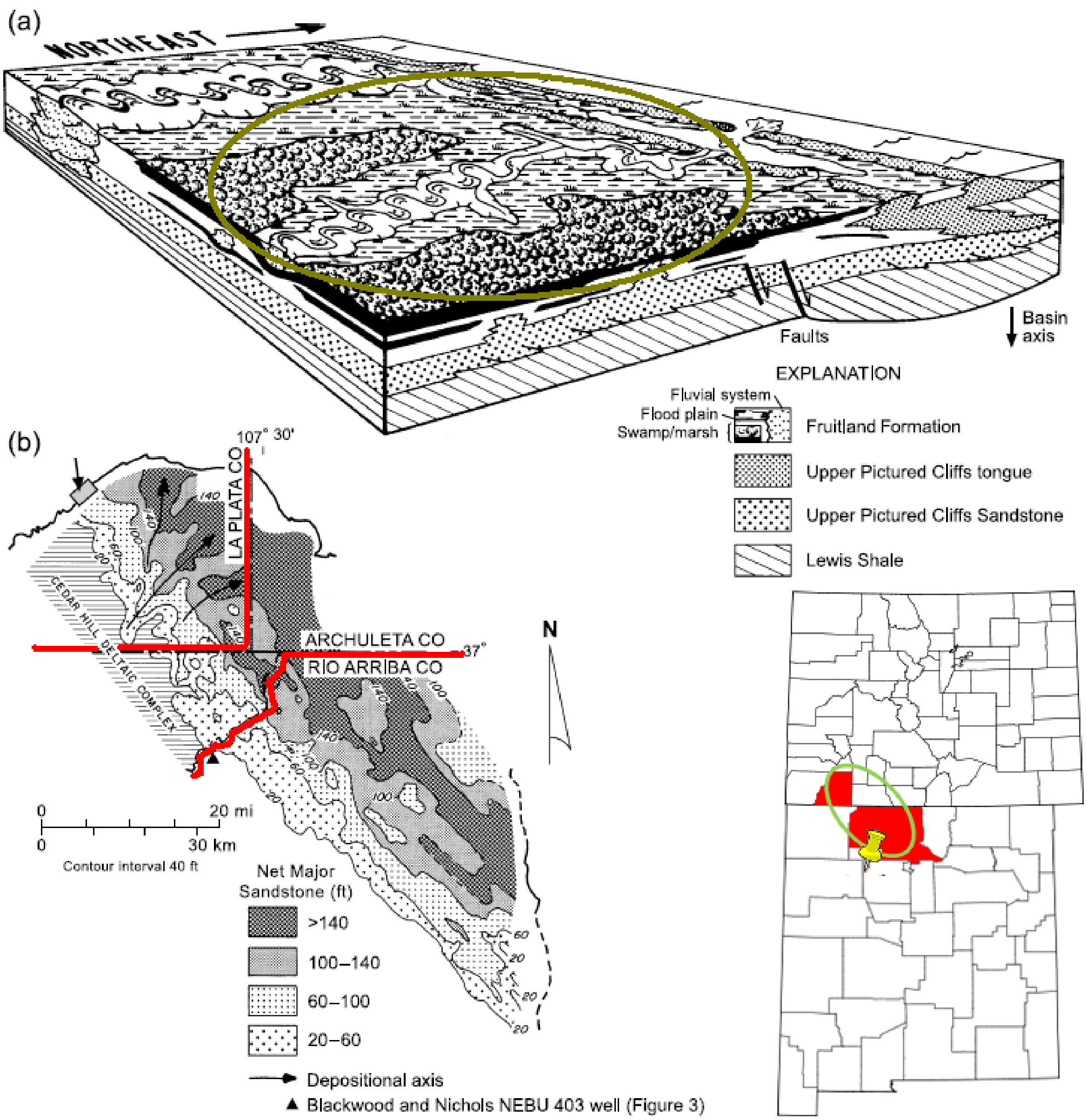



*Barracuda Field seismic expression. Reservoir has single-cycle expression with relatively high negative amplitudes. Progradational deltaic packages, overlying reservoir interval, provide top seal. Faults offset feeder systems.*




*Barracuda geometric attribute expression. Thinning attribute demonstrates thinning to left in red and thinning to right in purple. Unconformity attribute: dark grey to black = areas of relatively parallel layers; yellow = areas of convergence. Reservoir interval is highlighted by dotted line in both images.*

Figure 8: Barracuda Field seismic expression




(a) Depositional model for the Pictured Cliffs Sandstone, Fruitland Formation, and upper Pictured Cliffs tongues in the northern part of the San Juan Basin. Aggradation of shore-zone deposits in the Pictured Cliffs Sandstone may have been the result of increased subsidence along a basin homocline northeast of a hinge line or may reflect cycles of marine transgression during rates of increase of coastal onlap (Pashin, 1998). Peat accumulations may have also helped stabilize Pictured Cliffs barrier sandstones (McCabe and Shanley, 1992). (b) Net thickness of major sandstones in all three upper Pictured Cliffs Sandstone tongues (UP1, UP2, and UP3) in the northern part of the San Juan Basin. The Cedar Hill deltaic complex, inferred from irregular contours in the northwestern part of the basin, is interpreted to have provided sediments that were reworked along strike (southeastward) in a barrier-strand-plain complex. Modified from Ayers et al. (1994).

Figure 9: Depositional model for the Fruitland Formation

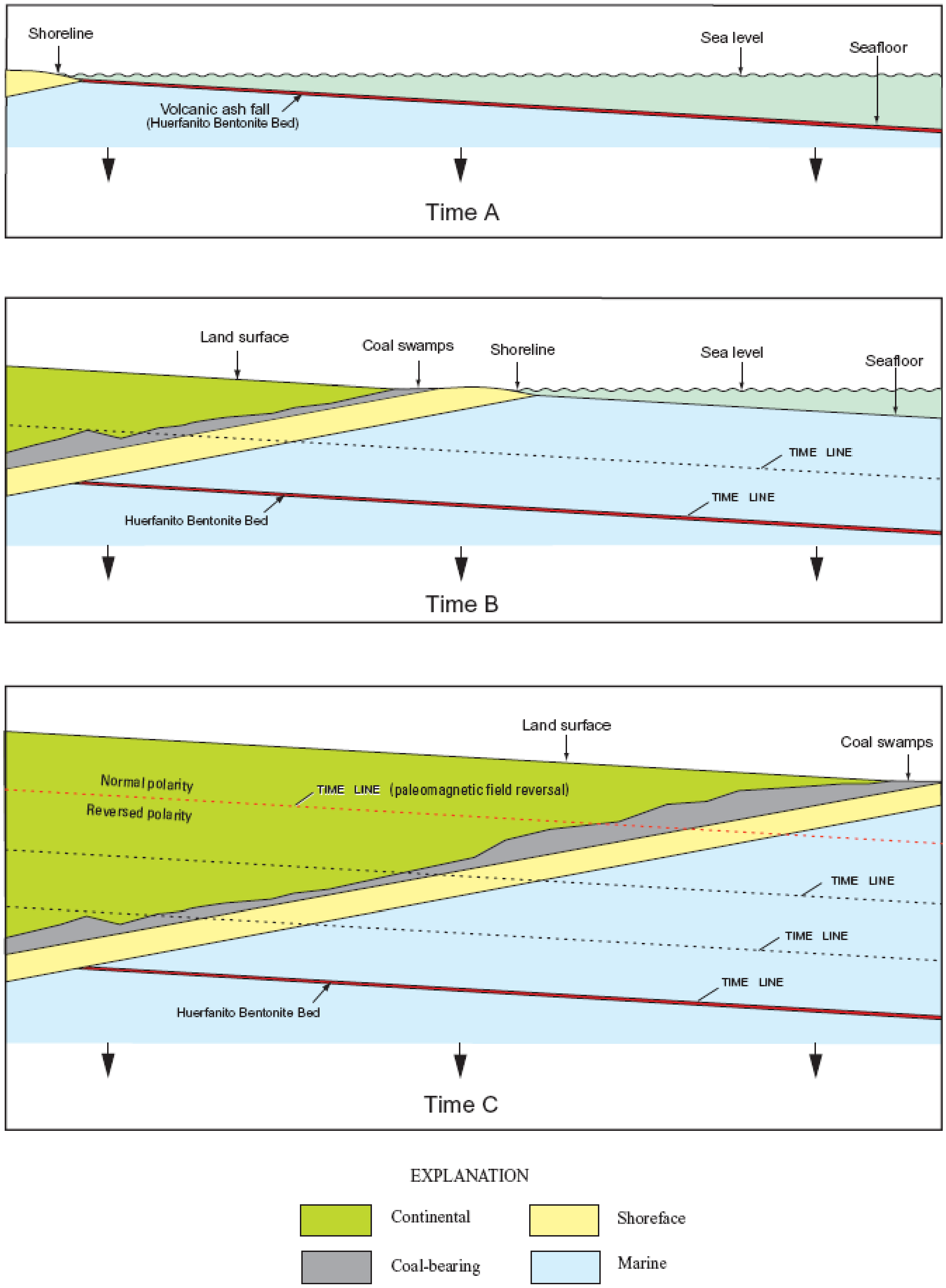



Figure 10: Model of the deposition shoreface sands in the Fruitland Formation, NM

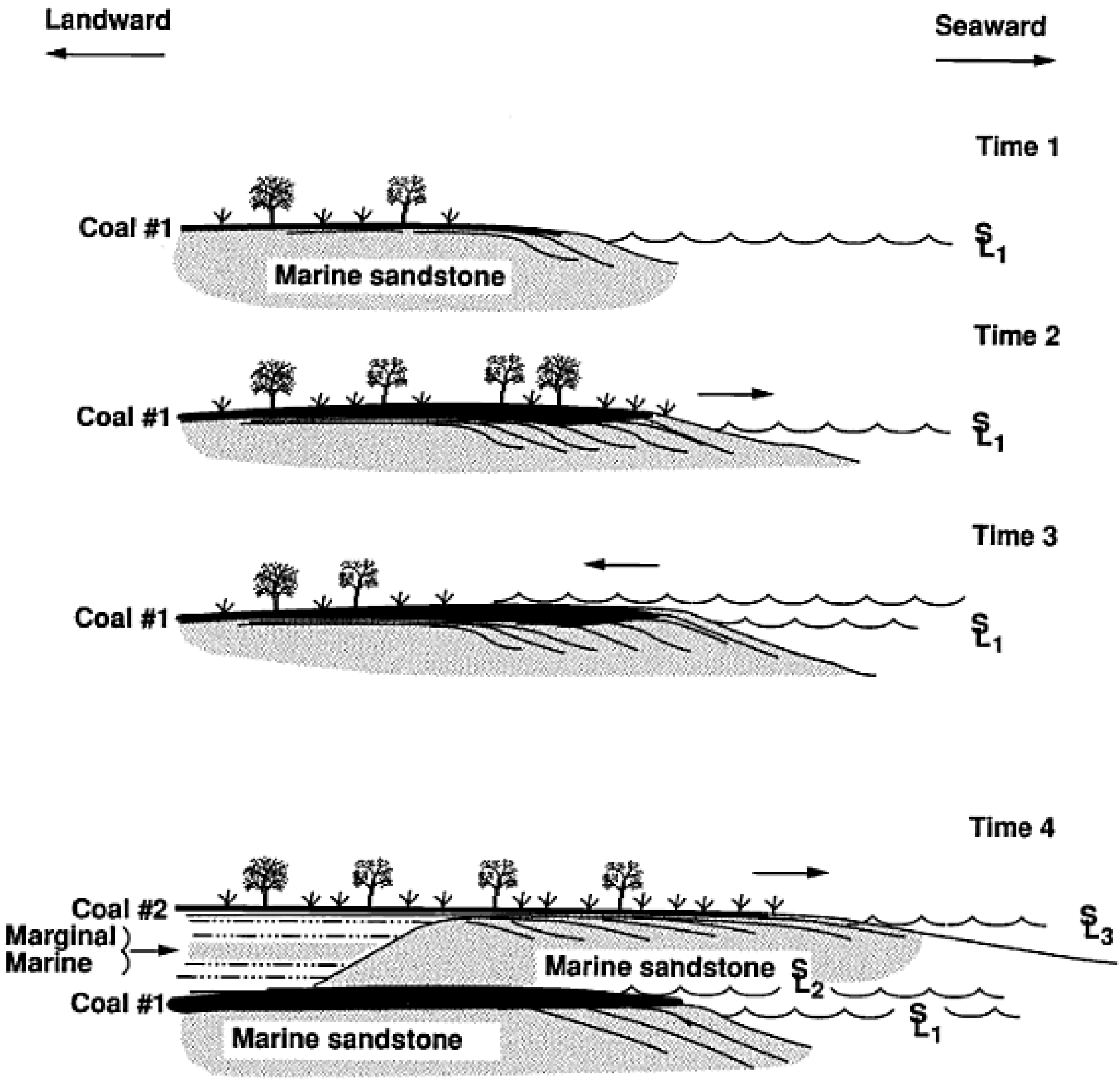



**Illustration of the formation of parasequence boundaries in the nonmarine/marginal marine setting. During time 1 and time 2, the coal-forming environment migrates seaward as the shoreline actively progrades basinward. In time 3, a relative rise in sea level terminates the progradational event resulting in a parasequence boundary and a landward migration of the shoreline. Because of the transgression, coal #1 is bracketed by marine sandstone. The top of coal #1 is the parasequence boundary associated with the first marine sandstone. In time 4, a second marine parasequence is seen. The overlying coal (coal #2) forms the top of this second parasequence and, where traced landward, defines the upper parasequence boundary for the nonmarine/marginal marine portion of the parasequence.**

Figure 11: Formation of parasequence boundaries in the nonmarine/marginal marine setting

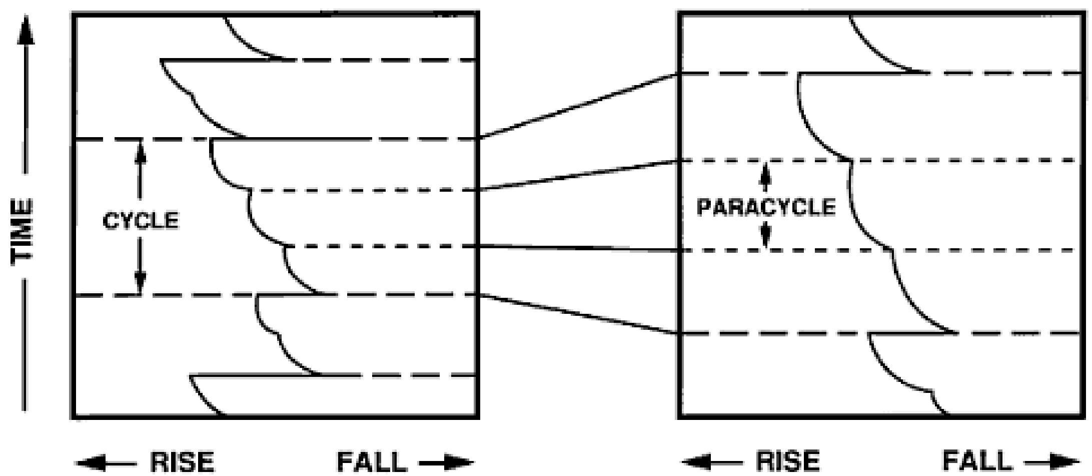



Figure 12: Parasequences

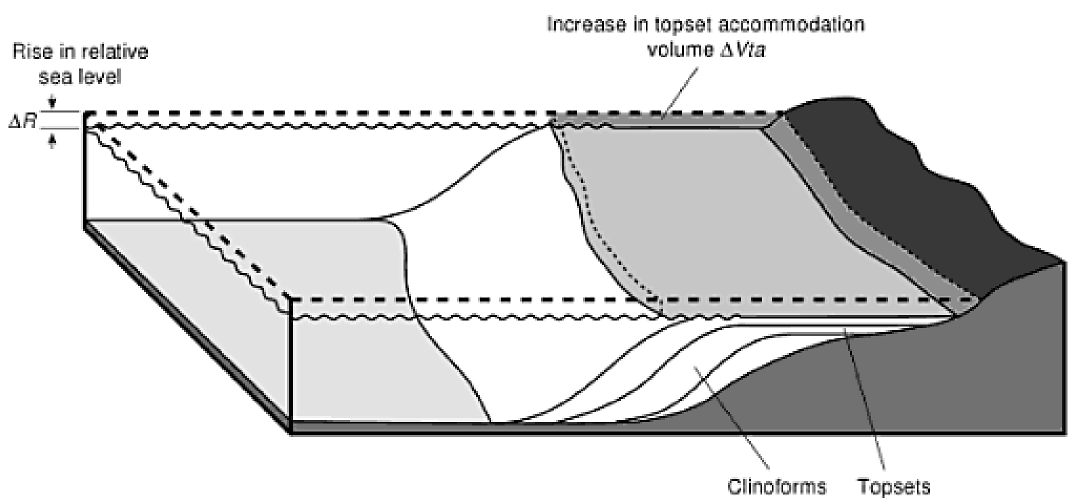



Figure 13: Topset Accumulation Volumes