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Eduard Suess' concept of eustatic sea level movements during his research in the Moldanubicum in Lower Austria: The cross-section Eggenburg-Horn

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Abstract. At the Archive of the History of Geology at the University of Vienna exists a partial estate of Eduard Suess, the first professor for Palaeontology and Geology at the University. A very interesting, drafted and coloured document is a cross-section between the medieval towns of Eggenburg and Horn, 60 km north of Vienna. The creation of this cross-section can be dated back to the years between 1859 and 1862. Suess also mapped the sediments of the "Eggenburg Sea" in the area (Tertiary, Miocene age). The names of the fossils deposited in the "Eggenburg Sea" were listed by Eduard Suess during his fieldtrips in this area. They bear witness to the theory of sea level movements – eustatic sea level movements – developed by Eduard Suess. Here he formulated his first ideas about an ancient sea, later named Tethys.

Keywords: Eduard Suess – eustatic sea level movements – Geology of Lower Austria – Bohemian Massiv – hand-crafted cross-section

Editor's Note: All map sheets open from right to left. Sheet 1 is on the right-hand side (east), the last sheet (18) is on the left-hand side (west). The author has numbered the individual sheets of the cross-section from right to left.

Introduction

Eduard Carl Adolph Suess was born on 20th August 1831 in London and died on 26th April 1914 in Vienna. He was one of the well-known geologists of the time. With his important scientific publications such as *Das Antlitz der Erde* – "The Face of the Earth" (Suess, 1883, 1888, 1901, 1909) he laid the foundation of the history of the Earth at the beginning of the 20th century.

During the new organisation of the estate of Suess in the Geological Archive the author discovered the hand painted cross-section. It gives us a detailed geological introduction to the area of Eggenburg and Horn and to the history of the local geology. In his field research in northwestern Lower Austria, Suess concentrated on paleontol-

ogical and geological studies. Part of these studies were located between the two towns of Eggenburg and Horn. The geological setting belongs to the area of the Moldanubicum, a part of the Bohemian Massive. Between Eggenburg and Horn existed the "Eggenburg Sea", sediments of Miocene age and the Bunte Serie with metamorphic sediments.

In the following discussion the single sheets of the cross-section are presented in connection with Eduard Suess' publication of the Imperial Academy of Science in Vienna, his comments in his *Erinnerungen-* (Memories) and in his book *Das Antlitz der Erde*. And finally, the result of these field studies in the Bohemian Massive led Suess to a new theory, the eustatic sea level movement, today known as transgression and regression.



Fig. 1. Portrait of Eduard Suess (1913). Geological Archive. Inv. Nr. GA 1. Size: 11,3 x 15,3 cm.

Geognostic map of a part of Lower Austria

The following geological map of the area (Fig. 2) with an overview of the location was the basis of the discussion in the proceedings of the Imperial Academy of Science by Eduard Suess (Suess, 1866, p. 91). Suess used the map during his fieldtrips in the area of Eggenburg and Horn. This map was the first geological map for this area done by the geologist Johann Czjzek (1805-1855).

The Bohemian Massiv and the Moldanubicum show the typical reddish colours and the Bunte Serie with its metamorphic sediments, such as marble, quartzite, graphite shists and amphibolites which are crossing the Moldanubicum in black strips from north to south. Green and yellow colours on the right side – east – document the sediments of the Vienna basin. A very unique part of the map are the cross-sections surrounding the geological map, giving an insight to the rock formations.

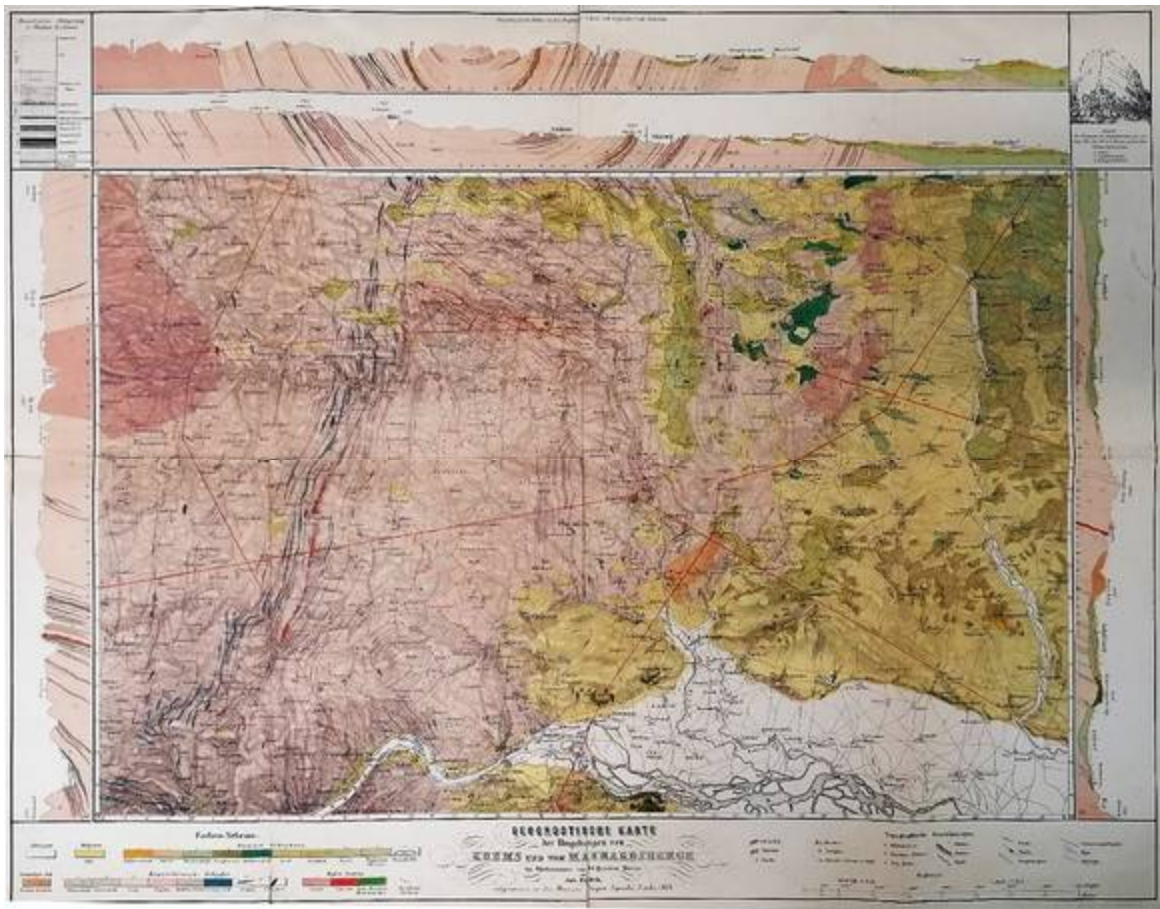


Fig. 2: Johann Čzjzek (1849), Geognostische Karte der Umgebungen von Krems und dem Mannhartsberge (1848). Geological Archive, Inv. Nr.: KS 1/ L 4.

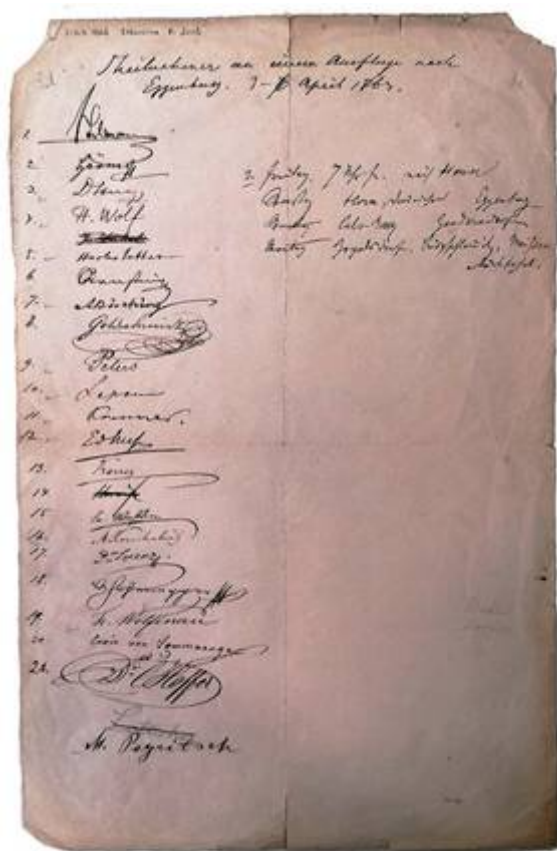
The cross-section Eggenburg-Horn

The Eggenburg-Horn cross-section, drawn by Eduard Suess with watercolors and black ink, has a total length of 433.5 cm and consists of 18 individual sheets of strong, smooth paper with these dimensions: height 39.2 cm and a variable width of each from 22.5 to 24.5 cm.

The sheets are bound together with strips of linen, so that this cross-section also held up well during the field excursions in the Eggenburg area

that Suess made with his students and colleagues.

In the Geological Archive exists a document about the excursion to Eggenburg in Cabinet 1, Box 20. Eduard Suess had created a sheet with the date of the excursion and the signatures of the participants. 21 students und interested people took part in this impressive excursion. The author was able to decipher the signatures of 19 participants (Fig. 3).



Transcription:

*Theilnehmer an einem Ausflug nach Eggenburg.
3.-6 April 1863.*

[participants on the excursion to Eggenburg]

Seemann, Hörnes, Stiny, Wolf, Hochstetter, A-tisching, Goldschmidt, Peters, Lepron, Prenner, Suess, Karrer, Kornhuber, Lorenz, Hohenegger, Wolfinau, Sommeruga, Hoffer, Peyritsch

[Destinations]:

3. Freitag 7 Uhr Fahrt nach Horn

[3. Friday trip to Horn by train]

Samstag Horn nach Eggenburg

[Saturday Horn to Eggenburg]

Sonntag Calenderberg Gauderndorf

[Sunday Calenderberg Gauderndorf]

Montag Zogelsdorf, Burg Schleinitz, Maissau Rück-fahrt

[Monday Zogelsdorf, Burg Schleinitz, Maissau re-turn of the trip]

Fig. 3. Eduard Suess: Participants on an excursion to Eggenburg. 3.-6 April 1863. Geological Archive, Cabinet 1, Box 20. Size: 34,5 x 21 cm.

The creation of the cross-section Eggenburg-Horn can be dated back to the years between 1859 and 1862.

In his memories, published posthumously in 1916, Suess mentioned that he was studying the area in the surroundings of Eggenburg:

“The free weeks of the summers of 1860 and 1861 were devoted to studying the former shores of the extended Mediterranean Sea in the sunny wine-growing region that accompanies the edge of the Bohemian-Moravian

*Mountains from Retz to the Danube.*¹ (Suess, 1916, p. 137).

In 1866 Suess published a sketch of the cross-section from the western slope of the Vitus Berg via Eggenburg in a westerly direction to a prominent point, Galgenberg near Horn (sheet 16, 17) in the session reports of the Imperial Academy of Sciences in Vienna (Suess, 1866, board 1). Here Suess mentioned that between 1859-1862 he determined the Horn layers with the barometer and had them calculated in Vienna by the paleontologist and surveyor Ferdinand Stoliczka (1838-1874).

On the first sheet (= reverse side of the colored cross-section) of the original, the heading in black ink reads: "Eggenburg-Horn" and an additional

note done by the geologists Leopold Kober (1883-1970) and Alexander Tollmann (1928-2007):

Cross-section drawn and labeled by Eduard Sueß. Pencil inscription by Leopold Kober. Alexander Tollman.

*Explained in the 1860s*².

On the 3rd sheet (Fig 4) of the cross-section the colours of the individual rock layers are described below the graphic representation of the view from Eggenburg:

Sand – yellow-orange, Tegel – blue, Granite (basement) – red, limestone – green

The color violet stands for mica schist and is drawn for the first time on sheet 6; it is the dominant colour of sheets 7-12.

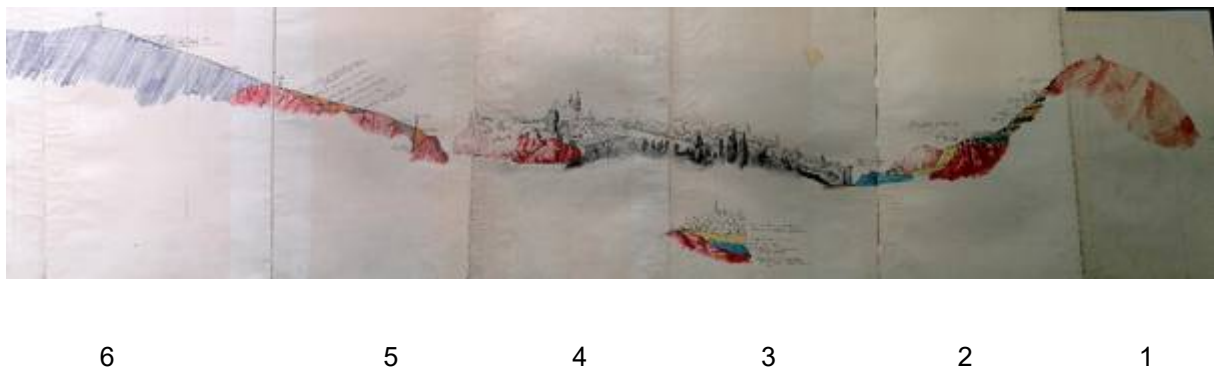


Fig. 4: Cross-section Eggenburg-Horn, sheet Nr. 1-6

In the following is a description of each sheet of the cross-section. The rock sequence of sheets 8-11 is not discussed as only purple-colored rocks, indicating mica schists with no obvious rock alteration and observation is present.

In his first review in the session reports of the Imperial Academy of Sciences Suess mentions that no noteworthy observations can be seen from Horn to the east.

*There are opposite slopes with similar tertiary strata which occur for a distance of several hours*³ (Suess, 1866, p. 87).

The distance between Eggenburg and Horn is 13 km.

The description of the path and the details of the fossil finds at the specific locations are recorded in great detail. His knowledge of the fossils

¹ Die freien Wochen der Sommer 1860 und 1861 waren dem Studium der einstigen Ufer des erweiterten Mittelmeeres an dem sonnigen Weingelände gewidmet, das den Rand des böhmisch-mährischen Gebirges von Retz bis an die Donau begleitet.

² Profil gezeichnet und beschriftet von Eduard Sueß. Bleistift-Beschriftung von Leopold Kober und Alexander Tollmann. Ausgeführt in den sechziger Jahren des 19. Jahrhunderts

³ Gegen Osten an jenseitige Abhänge, wo auf einer Strecke von mehreren Stunden, ähnliche Tertiärschichten vorkommen.

is worth noting. Eduard Suess is also a successful paleontologist. He states that the fossil finds provide clear evidence of the existence of a former sea.

On the first sheet of the cross-section east of Eggenburg, the Vitus Berg "Vitus Berg Ost" is shown, the red color stands for the granitic rock. From the Vitus Berg downwards in a westerly direction (sheet 2), the horizontally parallel layer sequences up to the "Basement of the Gerichtslehner" in the appropriate colors: blue-ochre, green and orange. At the base of the Vitus Berg near the "Gerichtslehner" lies the "marl with Lucina" colored in blue, above which Suess describes the following layers from the footwall to the hanging wall with significant fossils:

Panop. zahlreich aufrecht, O. digital., Pect., Mytil., Tapes Basteroti, sehr viel Pema [Panopea numerous upright, Ostrea digitalina, Pectunculus, Mytilus, Tapes basteroti, very much Pema; yellow].

Above that is the yellow-orange layer with the fossils:

Knollen mit Tell. Zonaria, Tumida, Turrit., Tr. patul.

[tubers with Tellina zonaria, Tumida, Turiella patula].

Today this corresponds to the Gauderndorf formation (Steininger, Roetzel, Şengör, 2015, p.24). The green and orange series are now part of the Zogelsdorf formation. The following fossils were deposited at the base of this formation (green color):

Nullip. Kik [Nulliporen Limestone, green].

Venus Pectuncul. [Venus Pectunculus].

Nullip. [Nullipors].

Hart. Lichtbraun Kik mit vl Quarz

[Hard light brown lime with lots of quartz; green].

große Pectines, große grem. Stke.

[large pectines, large grem. stone cores; yellow].

Serpulitenkik [Serpulitenkalk; green].

tax and Grus [Stones and Grus; yellow].

Serpulitenkik [Serpulitenkalk; green].

St.u. Grus [Stones and Grus; yellow].

Locker, groß. Blöcke u. Gran. darin Groß. Pectunculus

[Loose, large blocks of granite in Great Pectunculus; green],

Sand, T. Hörnesi selten, Pecten Bank und P. Malvinae, R3

[Sand, Terebratula Hörnesi, Pecten Bank, Pecten Malvinae. R3; yellow-orange].

Lockrer Kik mit vl Granit Trüm, T. Hoernes, Balan., Echinol

[Loose limestone with lots of granite debris, Terebratula Hörnesi, Balanus holgeri, Echinolamp. Linkii].

Above this sequence of layers, the granite base rock begins again, leading to the summit of Vitus Mountain.

On the 3rd and 4th sheet, Eduard Suess recorded the distinctive buildings and structures of the town of Eggenburg and the medieval town wall.

In the session reports of the Imperial Academy of Sciences (Suess, 1866, p. 103), Suess mentions the basement below the Gasthof zur Sonne lying 15 feet below the pavement with the fossils Mytilus Haidingeri, Ostrea lamellosa and Mytilus debris.

The 5th sheet indicates granitic subsoil. Above there are small sequences of sediments and tegel in the colors yellow-orange for "sandstone" and blue for Tegel.

Here Suess notes the fossils contained in the sedimentary rocks from the footwall to the hanging wall:

Ostrea longirostris, Mytilus, Cerithium plicatum, Tellina, Venus, Cerithium margaritaceum und plicatum, Lutraria sanna, Tellina multilamellata, Lamna, Mylobatis, Halitherium.

These fossils are indicative of the stratigraphic units today of the Kühnring Subformation and Burg-Schleinitz Formation.

The 6th sheet, west of Eggenburg, is shown in the uniform color violet for mica schist and a note of the fossils contained in the rock Tegel in the color blue:

T. Hoernes, Korallen, Pectl. Fichteli, [Terebratula hoernes, corals, Pectunculus fichteli]

Myt. Haidingeri, Turr. Cathedral., Panop. Meradi, Cardita crasia, Pinna, u.s.w. [Mytilus

haidingeri, Turritella cathedralis, Panopea menardi, Cardita crasia, Pinna, ect.].

Today, these sediments also belong to the Burg Schleinitz Formation.

The cross-section is continued to the west with violet watercolor paint in oblique lines, characteristic of mica schist, up to the settlement of Maria Dreieichen (7th - 13th sheet). It is a rock sequence with no further discussion or evidence of any other geological event.

In the publication of the session reports of the Imperial Academy of Sciences (Suess, 1866, p. 103) Suess presents the rock sequence in minute detail with the fossils found.

This is again followed by the granitic rock in red watercolor paint, which piles up in the direction of Horn to form the Galgenberg (15th - 18th sheet) and appears as the basement near the town of Horn.

Eduard Suess did not date this hand-colored cross-section, but in his book "Erinnerungen" he gives the period between 1860 and 1861 when he went to Eggenburg for intensive research (Suess, 1916, p. 137).

He summarizes the nature observations around Eggenburg, which led him a few years later to the conclusion and a new thesis, that the observed height conditions and the different sea deposits in this area would not be possible through the raising of a land, but only through the lowering of a water level.⁴

"Only fifteen years later [...] I dared to express this view publicly. First all the facts, such as the altitude, the fossil Conchylia, etc., had to be traced as precisely as possible. Today it is known as the doctrine of the eustatic sea level movements. This was established in the Eggenburg area". (Suess, 1916, p. 139).

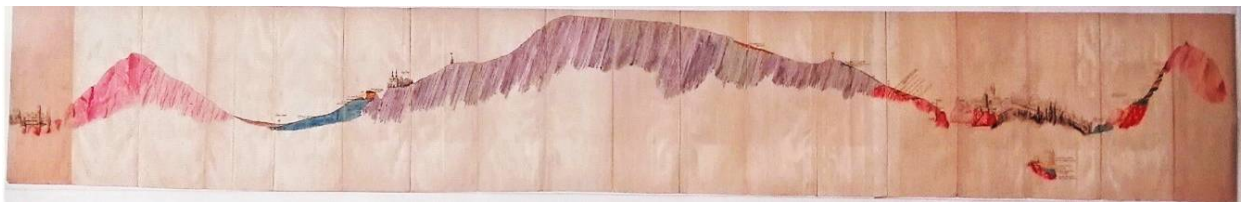


Fig. 5: Copy of the Cross-section Eggenburg-Horn. Geological Archive, Inv. Nr. GA 39. Size:433.5x24cm. (Hamilton, 2021).

A short description of these Eggenburg strata is already given in Franz Ritter von Hauer's work "Geologische Uebersichtskarte der österreichischen Monarchie" from 1869 (the punctuation and arrangement of the text have been retained here):⁵

Eggenburg, layers of. Neogene.

1866 Suess, Akad. Vol. 54, Part I, p. 113. - Eggenburg, small town in Austria below the

Enns, district of Ob. Mannh. Berg [Mannhartsberg], OSO. of Horn.

The fourth and highest of the stages, counted from the bottom, into which Suess divides the Neogene Tertiary formations of the extra-Alpine Vienna Basin at the foot of the Mannhart.

It is divided into two limbs, the lower one of solid sandstone (Molasse sandstone) with

⁴ *Zuerst mußten die Tatsachen, wie die Höhenverhältnisse, die fossilen Konchyliden u. a., so genau als möglich verfolgt werden [...]. Aber erst fünfzehn Jahre später, [...] durfte ich es wagen, diese Ansicht öffentlich auszusprechen. Heute nennt man sie die Lehre von den eustatischen Strandbewegungen. Im Gelände von Eggenburg ist sie geboren.*

⁵ *Eggenburg, Schichten von. Neogen.*

Suess, Akad. Sitzungsab. Bd. 54, I. Abth., p. 113. – Eggenburg, Städtchen in Österreich unter der Enns, Kreis Ob. Mannh. Berg, OSO. von Horn.

Die von unten gezählte vierte und oberste der Stufen, in welche Suess die neogenen Tertiärbildungen des ausseralpinen Wiener Beckens am Fusse des Mannhart gliedert. Sie zerfällt in zwei Glieder, dessen unteres aus festem Sandstein (Molasse-Sandstein) mit Panopaea Menardi, Pholodomya, Solen u.s.w., und deren oberes vorwiegend aus Kalkstein, zum Theile Nulliporenkalk mit Pecten aduncus, Echinodermen, Terebratula Hörnesi u.s.w. besteht. Nach Suess ist dieser Nulliporenkalk nicht als ein Aequivalent des Leithakalkes zu betrachten, sondern über ihn erst würden der Schlier und über diesen die Vertreter der Marinschichten des Alpinen Beckens folgen, deren höchste Stufe der Leithakalk bildet.

Panopaea Menardi, Pholodomya, Solen etc., and the upper one predominantly made of limestone, partly Nullipore limestone with Pecten aduncus, Echinoderms, Terebratula hoernesii, etc. consists. According to Suess, this Nullipore limestone is not to be regarded as an equivalent of the Leitha limestone, but only above it would the Schlier follow and then the representatives of the marine layers of the Alpine basin, the highest level of which is the Leitha limestone (Hauer, 1869, p. 169).

Eustatic sea level movements

Suess explained the term “eustatic sea level movement” in his book “Das Antlitz der Erde” (The Face of the Earth) ⁶ (Suess, 1888, p. 680-681; 688):

The globe is sinking; the sea follows. But while the subsidence of the globe is localized, the subsidence of the ocean spreads over the entire wetted surface of the planet. A general negative movement occurs [...] and refer to this group as eustatic movements.

The formation of ocean basins causes episodic, eustatic, negative movements. [...]

The thick sediments of prehistoric times and the erosion of the mainland, which are in many places measure thousands of feet, show how significant these quantities were and are. There is a very slow but continuous filling of the oceanic areas, which must bring about a general displacement of the seas from their depths, and at the same time the transgression is facilitated by the progressive degradation of the mainland. The formation of the sediments causes continuous, eustatic, positive movements of the beach time.

Suess discussed the negative and positive movements of the sea level, today it is referred to as transgression and regression of the sea level.

Conclusion

The most impressive part of the cross-section Eggenburg Horn are the sheets Nr. 1 to 6 with the representations of the geological conditions and fossil finds.

Suess linked numerous discoveries of fossils with the geological settings. He had published these ideas at the session reports of the Royal Academy of Science in Vienna with the geological conditions. There he combined the findings of the two disciplines of paleontology and geology. The combination of these two disciplines led Suess to new and fundamental insights. The representations of the geological conditions around the Eggenburg area are evidence of these new theories. Also the excursions with his students added to his research.

The theory of eustatic (beach motion) sea level fluctuations arise from transgression and regression of shorelines as a sea floor elevation changes over geological time. Suess developed this fundamental theory during his geological excursions through the rolling hills of the Molasse area surrounding the town Eggenburg in Lower Austria. In his “Erinnerungen” (Memories) he describes how this theory was born and that the area surrounding the granite hills were not established through the raising of the land, they were developed by the sinking of the sea level and the fossils he found underline his theory

In essence, this fundamental idea of sea level movements in the geological record was born there in Eggenburg and is finally used as a widely accepted theory around the world.

⁶ *Der Erdball sinkt ein; das Meer folgt. Während aber die Senkungen des Erdballes örtlich umgrenzt sind, breitet sich die Senkung der Meeresfläche über die ganze benetzte Oberfläche des Planeten aus. Es tritt eine allgemeine negative Bewegung ein [...] und bezeichnen diese Gruppe von Bewegungen als eustatische Bewegungen.*

Die Bildung der Meeresbecken veranlasst episodische, eustatische, negative Bewegungen. [...]

Die mächtigen Sedimente der Vorzeit und die an vielen Orten nach tausenden von Füssen messende Abtragung der Festländer lehren, wie bedeutend diese Mengen waren und sind. Es findet ein sehr langsames, aber unausgesetztes Auffüllen der oceanischen Gebiete statt, welches eine allgemeine Veränderung der Meere aus ihren Tiefen hervorbringen muss, und zugleich wird die Transgression durch die vorschreitende Erniedrigung der Festländer erleichtert.

Die Bildung der Sedimente veranlasst ununterbrochene, eustatische, positive Bewegung der Strandlinie.

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