

Original Paper

Do Norwegian Textbooks for Compulsory Education Promote Geological System Thinking?

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Abstract

Geology is one of many topics in the Norwegian curricula for Natural Science and Geography in compulsory education. System thinking is a strategy to promote conceptual development. The purpose of this study is to investigate how geological systems are presented in Norwegian science and geography textbooks for years 1-10. The geological system for oil and gas formation is explicit in the curriculum; the plate tectonic cycle and the rock cycle are not. 13 best-selling textbooks were examined showing that single components of geology are introduced at years 1-4. Elements and processes of rock formation and plate tectonics are introduced at years 5-7 and further developed at years 8-10. Oil and gas formation have a short introduction at years 8-10. The textbooks do cover the geology aims in the curriculum satisfactory except for oil and gas formation. One textbook presents the whole rock cycle, and one the plate tectonic cycle. The other textbooks present elements and processes but not as holistic geological cyclic systems.

Keywords

system thinking, geology, earth science, compulsory education, science textbooks, geography textbooks

1. Introduction

The plate tectonic cycle is shaping the Earth's geosphere, driving the rock cycle, and opening the oil and gas formation process. These Earth systems are all implicit or explicit in the Norwegian curriculum for Natural Science (from here: Science) and for Geography. Different methods are used for developing Earth system thinking among pupils. In Norway the textbooks are crucial in all learning processes in Science and Geography.

1.1 Earth System Thinking

Professor Wynne Harlen and her international team of reputed professors in science education write in *Principles and big ideas of science education* that “All students should leave school with a basic understanding of the ideas and procedures of science” (Harlen, 2010, p. 1). One of their big ideas *about* science is:

Science assumes that for every effect there is one or more causes (Harlen, 2010, p. 23, p. 44).

In *Working with Big Ideas of Science Education*, the same team reformulates this idea: “Science is about finding the cause or causes of phenomena in the natural world” (Harlen, 2015, p. 16). They now point to an important aspect of The Nature of Science and Education for Scientific Literacy—the search for cause-effect-connections.

One big idea of science is:

The composition of the Earth and its atmosphere and the processes occurring within them shape the Earth’s surface and its climate (Harlen, 2010, p. 21, p. 32, 2015, p. 15, p. 24).

About this idea Nir Orion and Charles R. Ault Jr. (2007, p. 660) write:

We live in a cycling world that is built upon a series of subsystems (geosphere, hydrosphere, biosphere, and atmosphere) that interact through an exchange of energy and materials (Orion & Ault, 2007, p. 660).

The processes shaping the Earth’s surface and climate are cyclic systems and subsystems.

After reviewing numerous articles about teaching and learning earth science, Orion and Ault (2007, p. 668) state that “current earth science education is characterized by a shift toward a system approach to teaching and curricular development”. Is the shift to system thinking explicit in Norwegian curriculum and textbooks for compulsory education when presenting the composition of the Earth and the processes occurring within it, to understand how the Earth’s surface is shaped?

1.2 Teaching for Geological System Thinking

Harlen’s (2010, p. 25f, 2015, p. 18f) team presents three general models of progression in science teaching and learning:

Vertical curriculum: Complete a step before the next step can be taken. “Climbing a ladder”.

Lateral curriculum: Start by fitting a few pieces of related knowledge together to form a larger section that more easily can be recognised as parts of a whole. Then fit in further pieces making the section larger. “Completing a jigsaw puzzle”.

Spiral curriculum: Ideas in a domain are revisited in intervals and hopefully become more powerful each time. “Training for a marathon”.

When working with the big idea *The composition of the Earth and its atmosphere and the processes occurring within them shape the Earth’s surface and its climate*, Harlen’s (2015, p. 25f) team recommends to start with the atmosphere, i.e., the weather, at age 5-7, and wait for the solid surface of the Earth (geology) to age 7-11. The pupils start studying soil as “a mixture of pieces of rock of various sizes and the remains of organisms” and different kinds of rocks beneath the soil (ibid., p. 24). Next

step is the first attempt in geology “finding the cause or causes of phenomena”, here formation of the soil. “The action of wind and water wears down rock gradually into smaller pieces—sand is made of small pieces of rock and silt of still smaller pieces” (ibid.). At age 11-14 the continuation of the topic is about the energy from the Sun and from radioactive decay inside the Earth causing the processes shaping the Earth’s surface and its climate. At age 14-17 the geological goal is to understand that “Below the surface heat from the Earth’s interior causes movement in the molten rock. This in turn leads to movement in the plates which form the Earth’s crust, creating volcanoes and earthquakes. The solid surface is constantly changing through the formation and weathering of rock” (ibid.). This is a superficial description of some important elements and processes of the Plate Tectonic Cycle and Rock Cycle. However, the goal do not include the last and logical step: Bring the pupils to deeper understand of the cyclic nature of the two systems. Harlen’s team has recommended progression in geology education from age 5 to 17 as a Vertical curriculum.

The team means generally that a Lateral curriculum “has disadvantages in providing too little guidance to teachers and other curriculum developers in deciding appropriate learning experiences” (ibid., p. 18). A Spiral curriculum “breaks overall goals into several strands. Ideas within each strand are gradually developed over time, ... However, there is a risk of losing sight of connections between ideas in different strands that link them together in bigger ideas” (ibid., p. 19).

Yael Kali, Nir Orion and Bat-Sheva Eylon (2003) let 40 Israel students at grade 7 study Earth’s crust as a cyclic system in a program partly based on field trips. The pupils’ system thinking abilities were assessed in open-end tests during the program on a continuum from Low (“A completely static view of the system”) to High (“Understanding the cyclic and dynamic nature of the system”). They concluded: Getting meaningful understanding of the rock cycle requires high levels of systems thinking.

With appropriate teaching students were able to acquire systems thinking in the context of the rock cycle (Kali, Orion, & Eylon, 2003).

Orion together with another Israeli colleague Orit Ben-Zvi-Assaraf has through their project Blue Planet, taught the water cycle in grade 8. They “distilled” eight hierarchic characteristics of system thinking from low to high level (Ben-Zvi-Assaraf & Orion, 2005, 2010a, 2010b) (Table 1).

Table 1. Characteristics of System Thinking from 1 Low to 8 High Level

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1. The ability to identify the components of a system and processes within the system
 2. The ability to identify relationships among the system’s components
 3. The ability to organize the systems’ components and processes within a framework of relationships
 4. The ability to make generalizations
 5. The ability to identify dynamic relationships within the system
 6. Understanding the hidden dimensions of the systems
 7. The ability to understand the cyclic nature of systems
 8. Thinking temporally: retrospection and prediction
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Based on their teaching and accompanying research, Ben-Zvi-Assaraf and Orion (2010b) developed the *STH model*—System Thinking Hierarchical—for teaching accordingly to students' development of system thinking (Table 2).

Table 2. The STH Model—System Thinking Hierarchical Model—Based on Characteristics in Table 1

A. Analyses of system components (characteristic 1)

B. Synthesis of system components (characteristics 2, 3, 4, 5)

C. Implementation (characteristics 6, 7, 8)

Level A must be completed before turning to teaching for level B etc. The basic structure of the STH models is Harlen's (2010, p. 25, 2015, p. 18) Vertical curriculum.

1.3 The Plate Tectonic Cycle and Subsystems

The plate tectonic cycle is the main system shaping the Earth's geosphere. The rock cycle and oil and gas formation are subsystems. The plate tectonic cycle starts with a supercontinent rifting up. The first cycle started ca.3.0 billion years ago. One complete cycle takes from 300 to 500 million years. The most recent supercontinent Pangea was formed by collision of continents ca.300 million years ago (For a good geological textbook, see Ramberg, Bryhni, & Nøtvedt, 2008). In 1912 the meteorologist and polar-researcher Alfred Wegener (1912) lanced his theory of continental drift. The hypothesis was controversial and not accepted because Wegener had no good ideas of why the continents should drift around on the Earth. Thanks to the geophysicist John Tuzo Wilson the idea of continental drift was taken up again in the 1970-ies. During 1962-1969 Wilson wrote several worldwide acclaimed articles about plate tectonics causing continental drift, sea floor formation and island formation (Wilson, 1963). Due to his pioneering works, the plate tectonic cycle is sometime called Wilson cycle. However, the causes of the cycle are still disputed. One theory is that the cycle is a convection cell caused by the Earth's warm interior, and the continents are drifting on top of the cell (Figure 1). The competing theory is that because the sea ridge is at a slightly higher level than the subduction zones ("Trench", Figure 2), the sea floor plate ("slab") is pulled by gravity towards subduction.

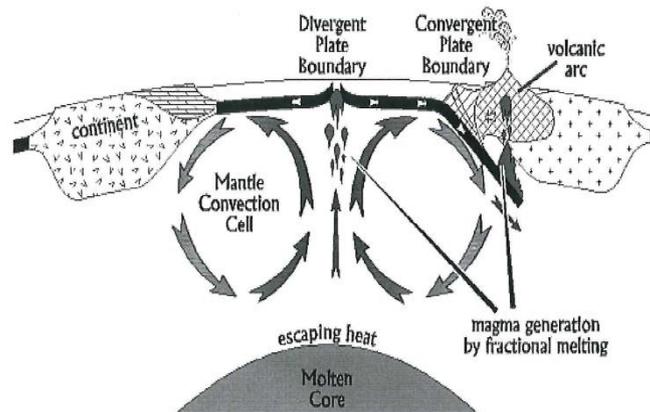


Figure 1. The Plate Tectonic Cycle Caused by Convection (JMU, n.d.)

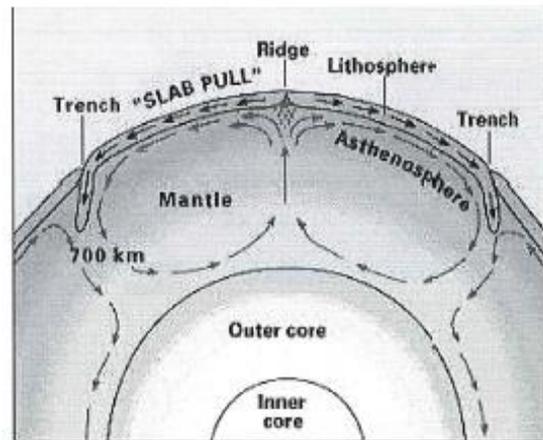


Figure 2. The Plate Tectonic Cycle Caused by Gravity ("Slab Pull") (UCLA, n.d.)

The rock cycle is driven by the plate tectonic cycle. We can start the story in Figure 3 when new material added from depth or from upcoming magma (Figure 1) slowly cools and the crystallization starts within the Earth. In volcanic eruptions (Figure 1) the magma is coming directly up as lava and cools rapidly on the Earth's surface. Weathering and erosion little by little degrades these igneous rocks to sediments. By deposition and lithification sediments turn into solid sedimentary rocks. If igneous or sedimentary rocks are forced down by the plate tectonic cycle (Figures 1, 2, 3), they will suffer increasing heat and pressure and might turn into metamorphic rocks. The plate tectonic cycle could force them further down into the magma or up to the surface.

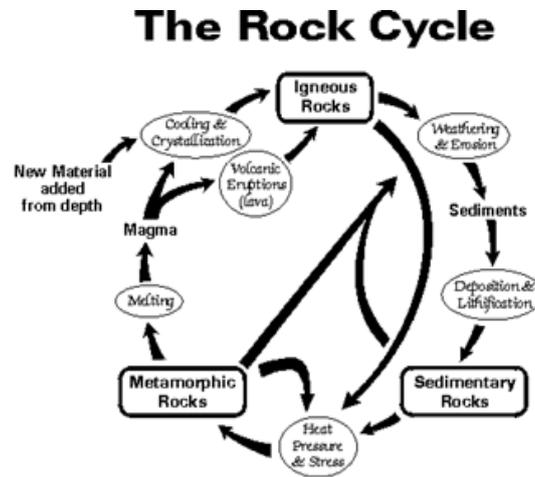


Figure 3. The Rock Cycle (USGS, n.d.)

The oil and gas formation is also driven by plate tectonics. In the North Sea the process started almost 200 million years ago. When rifting a continent, a sea bay opens between new continents. The bay could be filled with sand from rivers. Over time the sand lithify to sandstone. This is going to be the reservoir rocks for oil or/and gas. By further tectonic movement the sea level rises and the sandstone is covered with clay from rivers. This is going to be the cap rock of the basin. The continents move further apart and the sea floor breaks up and form islands. Some islands are forced vertical up, some down. The sea level is rising above the islands. If temperature is high and CO₂ level is optimal, lots of sea-weed, planktons and plants will live in the sea. When they die, they sink to the bottom, forming sediments. In the depths between the original islands, the sediments together with clay are turning to be the fossilized source rock. The sediments are transformed to kerogen through a long process depending on pressure and temperature. When the continents move further apart the sea level is still rising. The source rocks are covered with deep layers of clay, later solidified to clay-slate. If the pressure and temperature rises, kerogen transforms to lighter oil and/or gas, which floats upwards. If it floats into sandstone sealed by cap rock, it is forming an oil and/or gas field. The field could stay under sea like in the North Sea or be lifted by tectonics to higher level (Figure 4) like in Saudi Arabia. It might seem that this system is linear because we put our drilling equipment into the reservoir rock and end the process. However, when the tectonic cycle is going on, even oil and gas trapped in sandstone will be forced down into the magma.

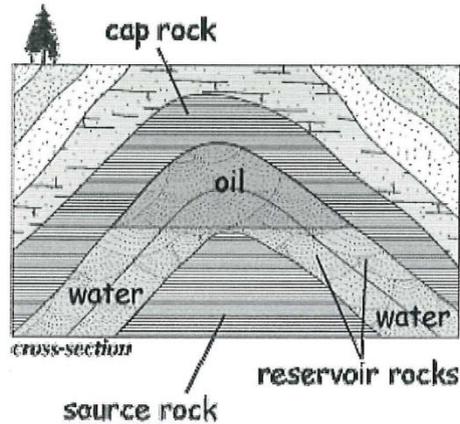


Figure 4. Rock Layers in an Oil Field (University of Wyoming, n.d.)

1.4 Geology in the Curriculum

The National Curriculum for Knowledge Promotion in Primary and Secondary Education and Training (in short *National Curriculum*, Directorate for Education and Training, 2006) was implemented in 2006. There are several geological competence aims in compulsory education, i.e., Year 1-10. The competence aims in National Curriculum are on three taxonomic levels: low, intermediate, high. The verbs tell the level (Directorate for Education and Training, n.d.). The verbs in the geological aims are “describe”, “register” on low level, and “explore”, “present”, “explain”, “recommend”, “converse”, “examine”, “interpret” on intermediate level. No geological aims are on high taxonomic level. Two general competence aims could include geological aspects in *Natural Science* (Directorate for Education and Training, 2013a). After Year 2 and 4 both aims are on low to intermediate taxonomic level:

The aims of the studies are to enable pupils to
 use one’s senses to explore the world in the local neighbourhood (Year 2)
 [and]
 use natural science terms to describe and present one’s own observations in various ways and
 recommend and converse about the possible explanations for what one has observed (Year 4)

The geological competence aim after Year 7 is on low to intermediate taxonomic level:

The aims of the studies are to enable pupils to
 describe how some minerals and rock types were formed and examine some of these types
 from nearby surroundings

The two geological competence aims after Year 10 are both on intermediate taxonomic level:

The aims of the studies are to enable pupils to
 explain the main characteristics of theories on how the earth is changing and has changed over
 the eons and the underpinning of these theories
 [and]
 explain how crude oil and natural gas have come about

Minerals and rocks are the building blocks in the rock-formation system, and “how some minerals and rock types were formed” is about the chain of cause-effect-processes in the rock cycle. The best theory about “how the earth is changing and has changed over the eons” is the plate tectonic cycle. Despite not using the concepts “plate tectonic cycle” and “rock cycle”, a reasonable interpretation of the aims is that teaching for geological system thinking is permitted in Science.

In *Geography* (Directorate for Education and Training, 2013b), the geological competence aim after Year 4 is on low to intermediate taxonomic level:

The aims of the studies are to enable pupils to
describe land formations and use geographic names to explore the landscape near one’s school
and home

The geological competence aim after Year 7 is on low to intermediate taxonomic level:

The aims of the studies are to enable pupils to
register and interpret traces left by the Ice Age in the place where one lives and explain what
the Ice Age meant to the formation of the terrain and the country as a whole

The two geological competence aims after Year 10 are on intermediate and low to intermediate taxonomic level respectively:

The aims of the studies are to enable pupils to
explain the basic forces of nature focusing on internal and external forces on earth, ...
[and]
describe and explain natural ... landscapes in the local community

Geography focuses on terrain formation and landscapes through all years in compulsory education. “Formation of the terrain” is supplementary to the rock formation aims in Science, as “internal and external forces on earth” are supplementary to the plate tectonics.

To sum up from National Curriculum: Teaching of geology in Science and Geography does in some way follow the STH model (Table 2): At Years 1 to 4 the pupils start level A if they explore and describe geological objects. At Years 5 to 7 the pupils should finish level A and start level B. At Years 8 to 10 the pupils should finish level B and start level C—at least to characteristic 6 (Understanding the hidden dimensions of the systems). For all geological educational objectives, the pupils are expected to reach an intermediate taxonomic level.

1.5 The Research Question

The National Curriculum in Natural Science and Geography is the *Formal Curriculum* (Goodlad, Klein, & Tye, 1979) established as regulations (i.e., Norwegian “law”) by the Ministry of Education and Research. The Formal Curriculum is interpreted by publishers and textbook writers to form textbooks to each subject and year. The textbooks are their *Perceived Curriculum* (ibid.). Many Norwegian science and geography teachers are leaning more to textbooks than to The Formal Curriculum when planning their teaching (Grønmo & Onstad, 2013, p. 165)—making their *Operational Curriculum*

(Goodlad, Klein, & Tye, 1979). That's why textbooks are crucial important for the pupils' educational outcome—*The Experiential Curriculum* (Goodlad, Klein, & Tye, 1979).

One of the bearing principles in The National Curriculum is that publishers, textbook writers, headmasters and teacher are free to choose appropriate teaching methods to every topic (Grønmo & Onstad, 2013, p. 91). The textbook writers could adapt to STH model, one of Harlen's models or other curricular models.

The research question is: *Do Norwegian textbooks for compulsory education promote geological system thinking?*

This question is twofold. First, do the textbooks include sufficient components and processes of geology to form the systems? Second, if so, are the components and processes presented explicit as geological systems or in a way that can promote geological system thinking through appropriate teaching?

2. Method

The population is all Norwegian science and geography textbooks for years 1-10 written for The National Curriculum from 2006 and the years to come. The sample is textbooks from the two best-selling Norwegian publishers *Aschehoug* and *Gyldendal* covering all years in science and geography. All are still in use in 2017. 13 (Table 3) of totally 32 books contained geological texts from 4 pages (5% of the book) to 74 pages (52%). The books have from 60% to 85% of the market at given subject and year according to the publishers own information (No official statistics are available).

Table 3. The Sample of Science and Geography Textbooks Containing Some Geological Texts

H. Aschehoug & Co (W. Nygaard):	Gyldendal Norsk Forlag AS:
<i>Cumulus 1, Naturfag og samfunnsfag</i> (Bjørshol, Lie, Råne, & Vedum, 2006)*	<i>Gaia 3, Natur- og samfunnsfag for barnesteget</i> (Holm, Jensen, Johnsrud, Langholm, Spilde, Utklev, & Bungum, 2006)
<i>Yggdrasil 5, Naturfag</i> (Gran & Nordbakke, 2009)	<i>Gaia 5, Naturfag</i> (Spilde & Bungum, 2006)
<i>Midgard 5, Samfunnsfag</i> (Aarre, Flatby, Høiby, & Sævedt, 2009)	<i>Gaia 5, Samfunnsfag</i> (Holm & Utklev, 2006)
<i>Tellus 8, Naturfag</i> (Ekeland, Johansen, Strand, & Rygh, 2009)	<i>Eureka 8, Naturfag</i> (Frøyland, Hannisdal, Haugan, & Nyberg, 2006)
<i>Tellus 9, Naturfag</i> (Ekeland, Johansen, Strand, & Rygh, 2010)	<i>Eureka 10, Naturfag</i> (Hannisdal, Hannisdal, Haugan, & Synnes, 2008)
<i>Matriks 8, Geografi</i> (Karlsen & Holgersen, 2006)	<i>Underveis 8, Geografi</i> (Birkenes & Østensen, 2006)
*only short book-names are used in the article	<i>Underveis 9, Geografi</i> (Birkenes & Østensen, 2007)
<i>Aschehoug</i> books' market shares: ca.20%-ca.55%	<i>Gyldendal</i> books' market shares: ca.30%-ca.45%
<i>Aschehoug</i> and <i>Gyldendal's</i> market shares together: Science books 80-85%, Geography books ca.60%.	

The texts in science and geography textbooks are multimodal (Mork & Erlien, 2010, p. 51) containing all written text, pictures, drawings, tables, etc. In this article “text” means the multimodal text. The main focus of analysis in geological texts is on the level of geological system thinking. Other aspects of text analysis like extent and linguistic presentation, quality of illustrations and readability are not discussed in this article.

The analyses are in three steps: First, the geological texts in a book are sorted on four categories: About Rock formation (R in Table 6), Plate tectonics (P), Landscape and land forming (L), Oil and gas formation (O). Land forming is seen as a part of rock formation. Second, the texts are checked against the curriculum content and taxonomic level for the actual year. Third, the level of geological system thinking is assessed on a scale from 1 (low) to 8 (high). The criteria are the eight characteristics of system thinking in Table 1. It is possible to present characteristics at high levels without having filled all lower characteristics. In Table 6 only the highest level in a text is used.

Headings, subheadings, quotes and illustrations are good representations of the content and system level of the text, and are used in chapter Results as circumstantial data.

3. Result

A brief reading of the textbooks shows that texts about stones, rocks and the rock formation process start on lower years than the plate tectonics. Oil and gas formation is presented only at years 8-10. The three systems will be presented separate in this order despite the geological fact that the plate tectonic cycle is the main process and the two others are sub cycles. Geography textbooks go into the processes forming landscapes, sometimes connected to rock formation or plate tectonics.

3.1 Geological System Thinking 1: The Rock Cycle

3.1.1 Years 1-4, Textbooks Covering Both Science and Geography

Cumulus 1 (pp. 24-27) has the first “geological” text in this sample at Year 1. Single components of geology (stones) are introduced with many pictures and drawings, and short written texts (Table 4).

Cumulus 1 (pp. 70-73) and *Gaia 3* (p. 140f) have texts and drawings showing and naming common Norwegian landscapes.

Table 4. The very First Written “Geological” Text at Year 1 (*Cumulus 1*, p. 25) is Printed in a Drawing (Right: Authors Translation)

<i>I Norge har vi mye stein</i>	In Norway there is a lot of stones
<i>Steiner er lette</i>	Stones are light
<i>Steiner er tunge</i>	Stones are heavy
<i>Steiner har mange farger</i>	Stones have many colours
<i>Sand er bitte små steiner</i>	Sands are tiny little stones

Gaia 3 (pp. 142-155) continues with texts about different landscapes: *Innsjøen* (The lake), *Bekker og elvar* (Creeks and rivers), *Høge fjell og flate vidder* (High mountains and mountain plateaus), *Fjellkjeder* (Mountain ranges), *Ein lang kyst* (A long coastline), *Fantastiske fjordar* (Amazing fjords).

3.1.2 Years 5-7, Science Textbooks

Yggdrasil 5's (pp. 138-157) headings are *Spennede steiner* (Exciting stones), introducing the most common rocks and minerals in Norway. *Fjell og steiner kan inneholde mange skatter* (Mountains and stones can hide many treasures), about silver-, copper- and iron-mining in Norway. *Hvordan fjellene ble til* (How the mountains were formed), describing how the Earth's internal and external forces gave us igneous rocks, sedimentary rocks, and metamorphic rocks.

Gaya 5N's (pp. 144-167) main heading is *En verden av stein* (A world of stone). The text starts with two plate tectonic subchapters *En planet blir født* (A planet is born) and *Ildkule med steinskorpe* (Fireball with a stone crust), illustrated like the upper part of the plate tectonic cycle (the "slab pull", Figure 2) with a volcano in the subduction area ("Trench", Figure 2), causing igneous rock formation. This is introduction to the rock-chapters *Hvorfor er steiner forskjellig?* (Why are stones different?), about minerals and rocks. *Magmatiske bergarter* (Igneous rocks). *Sedimentære bergarter* (Sedimentary rocks) and *Metamorfe bergarter* (Metamorphic rocks), all with common examples illustrated with photos. *Fjellet forteller* (The mountain as storytellers), about fossils and layers. *Ville vulkaner* (Wild volcanos). *Gaya 5N* is more comprehensive than *Yggdrasil 5*, both in written texts and illustrations.

3.1.3 Years 5-7, Geography Textbooks

Gaya 5S's (pp. 18-39) main heading is *Spor etter is* (Tracks from ice)—announcing that the chapter is about how the glaciations formed Norwegian landscapes. The subheadings are *Tykk is dekket Norge* (Thick ice covered Norway). *Verdens sterkeste bulldoser* (The world's strongest bulldozer [ice]). *Morener og flyttblokker* (Moraines and moving blocks). *Verdens største og sterkeste slipemaskin* (The world's biggest and strongest grind machine [ice]). *Striper og hvalskrotter* (Stripes and whale-body-shapes [bare rocks]). *På jakt etter merker og spor* (Searching for marks and tracks). *Spor etter iserosjon* (Tracks from ice erosion). *Spor isen har lagt igjen i avsetninger* (Tracks from ice: deposit material). *Fra havbunn til god jord* (From sea-floor to good soil). *Underlige spor* (Mysterious tracks).

Midgard 5's (pp. 130-133) text is also about how the glaciations formed Norwegian landscapes, but in a very short version compared to *Gaya 5S*. Both books are focusing on landscape formation. The only rock formation processes mentioned are erosion and weathering.

3.1.4 Years 8-10, Science Textbook

Eureka 8 (pp. 216-233) shows that rock formation is driven by plate tectonics. Except from that, the content is on the same level as in years 5-7.

3.1.5 Years 8-10, Geography Textbooks

Matriks 8 (pp. 30-55) starts with the plate tectonic chapter. Some of the facts are used in the rock chapter *Berggrunnen* (Basement rocks, pp. 56-71). The subheadings are *Bergarter* (Rocks), *Mineraler*

(Minerals). *Verdifulle bergarter* (Valuable rocks). *Bergarter varer ikke evig* (Rocks are not forever), explaining the rock cycle (Table 5). Matriks 8 is the only textbook in the sample using the concept *Bergartenes kretsløp* (The Rock Cycle) (p. 66) when presenting the cyclic nature of the systems with Figure 5. The accompanying text gives a comprehensive explanation of the formation of igneous rocks, sedimentary rocks, and metamorphic rocks.

Table 5. Text in Matriks 8 (p. 66) Placed over Figure 5 (Right: Authors Translation)

<i>Fordi jorda fortsatt er en levende planet, både på innsiden og utsiden, dannes det stadig nye bergarter. Men selv stein varer ikke evig! Bergartene inngår i et kretsløp der de “fødes” og “dør”.</i>	Because the Earth still is a living planet, both inside and outside, new rocks are continuously formed. However, even stones are not forever! Rocks are parts of a cycle where they are “born” and “die”.
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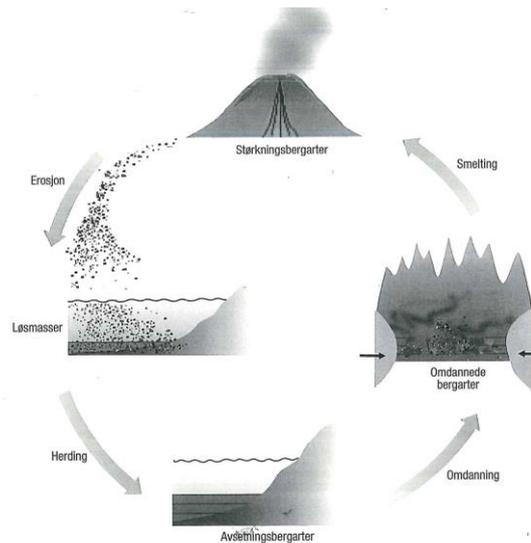


Figure 5. Matriks 8 (p. 66) is the only Textbook Using the Concept “Rock Cycle”

Figure-text to Figure 5 (author’s translation): *Bergartene inngår i et kretsløp som kan ta millioner av år* (The rocks are parts of a cycle lasting for millions of years).

Words in the figure: *Størkningsbergarter* (Igneous rocks), *Erosjon* (Erosion). *Løsmasser* (Loose deposits), *Herding* (Lithification), *Avsetningsbergarter* (Sedimentary rocks), *Omdanning* (Metamorphism), *Omdannede bergarter* (Metamorphic rocks), *Smelting* (Melting).

Underveis 8 have also a comprehensive text starting with the chapter *Jordas indre krefter* (Internal forces in the Earth, pp. 26-47), about plate tectonics and is continued by *Jordas ytre krefter* (External forces on Earth, pp. 48-77). This chapter is about how glaciation forms landscapes. Nothing but erosion and weathering are about rock formation.

Underveis 9 have texts about European landscapes with short references to *Underveis 8*, formation of mountain ranges, without mentioning plate tectonics.

3.2 Geological System Thinking 2: The Plate Tectonic Cycle

3.2.1 Years 5-7, Science Textbooks

Yggdrasil 5 (p. 150) have a very short written text about seven tectonic plates floating on magma. They could cause earthquakes and volcanos when colliding at boundaries. Volcanos produce lava, solidifying to igneous rocks.

Gaya 5N is described above. The tectonic chapter *Ildkule med steinskorpe* (Fireball with a stone crust, p. 148f) is a bit more comprehensive than *Yggdrasil 5*, both in written text and illustrations.

3.2.2 Years 8-10, Science Textbooks

Tellus 8's (pp. 52-56) main heading is *Jorda—den levende planeten* (Earth—the living planet), announcing that the chapter is about plate tectonics. The subheadings are *Den urolige jordskorpa* (The restless crust). *Jorda blir til* (The formation of the Earth), from the start 4.5 billion years ago. *Skall på skall innover i joda* (Shell on shell in the Earth). *Teorien om kontinentaldrift* (The theory of continental drift), about Alfred Wegener and his theory. *Havbunnen revner* (The sea floor rifts), starts with 1960-ies explorations of the rift zones and ridges. *Jorda skjelver* (The Earth quakes), about 15 tectonic plates and sea floors plates in movement causing earthquake, volcanism and mountain ranges along the boundaries, supported by a figure like the upper half of the cycle in Figure 1.

Eureka 8 (pp. 216-245) have also a comprehensive text under heading *Historien om jorda* (The Earth's history) with subheadings *Jorda* (The Earth). *Jordskorpa* (The Earth's crust). *Den urolige jordskorpa* (The restless crust), with Figures 6-8 showing the whole tectonic cycle. *Verdenskartet forandrer seg* (The world-map is changing). *Jordas byggesteiner* (The Earth's building blocks). *Gråstein finnes ikke* (Grey-rocks are not found). *Jordas hemmeligheter* (The Earth's secrets). *Ut på tur* (On a fieldtrip). *Alfred Wegener, "geologiens Darwin"* (Alfred Wegener, "the Darwin of geology") and *Geologifaget blir til* (The "birth" of geology), tells the story as an example of the evolution of geology as science.

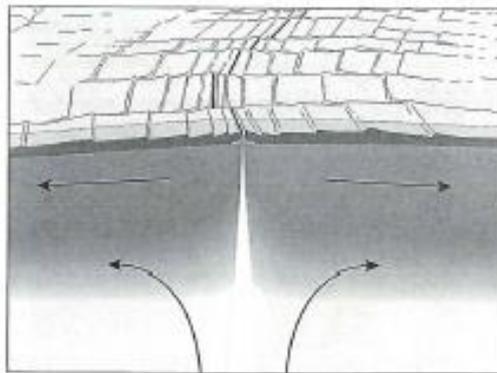


Figure 6. Eureka 8 (p. 222) Figure-Text (Author'S Translation): *Der platene beveger seg fra hverandre blir ny jordskorpe til* (When the Plates Move Apart New Crust is Formed)

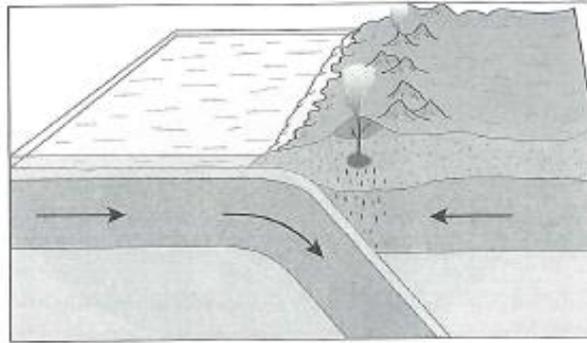


Figure 7. Eureka 8 (p. 223) Figure-Text (Author’S Translation): *Der jordskorpeplatene kolliderer blir fjell til* (When the Plates Collide Mountains are Formed)

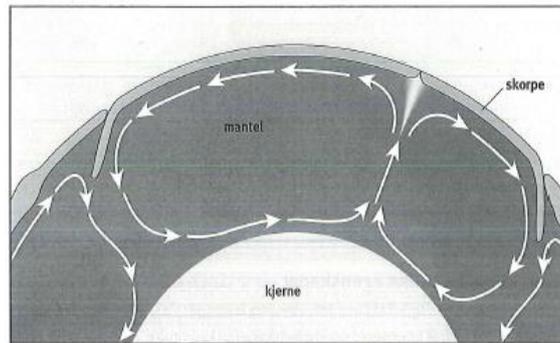


Figure 8. Eureka 8 (p. 225) Figure-Text (Author’S Translation): *Her ser du hvordan geologene tenker seg at strømmene i mantelen kan være* (Here You Can See How Geologists Think About the Currents in the Mantel)

Words in Figure 8: *mantel* (mantel), *skorpe* (crust), *kjerne* (core).

3.2.3 Years 8-10, Geography Textbooks

Matriks 8 (pp. 30-55, pp. 64-69) have a long description of how the drifting continental plates cause earthquake, volcanos, tsunamis and forming landscapes (continents, mountain ranges, deep sea trenches, sea ridges, islands). The last theme is supported by a figure (p. 50) like the upper half of the plate tectonic cycle in Figure 1.

Underveis 8 (pp. 26-47) covers the same themes, and has figures in three steps (“cartoons”) showing only the part of the cycle explaining how mountain ranges are building up.

3.3 Geological System Thinking 3: *The Oil and Gas Formation*

3.3.1 Years 5-7, Geography Textbook

Middgard 5 (p. 135). The process is mentioned in one sentence: “*Olje er sammenpressede rester etter planter og dyr som levde for mange millioner år siden*” (Oil is remainders of plants and animals pressed together many million years ago). This misconception is perhaps worse than nothing (See King (2010) about Earth science misconceptions in textbooks).

3.3.2 Years 8-10, Science Textbooks

Eureka 10 (pp. 74-75), the best textbook on this theme, uses only two pages and three illustrations (one is Figure 9) to describe the very complex geological processes of oil and gas formation, but uses 12 pages (pp. 76-87) describing the seismic, investigation, production, processing and use of oil and gas.

Tellus 9 (pp. 173-175) has a chapter *Oljeeventyret* (The oil adventure) with the subchapter *Hvor kommer naturgass og råolje fra?* (What is the origin of natural gas and crude oil?) The written text fills less than one page. "... råolje og naturgass stammer fra bittesmå dyr og planter som levde i havet for omtrent 150 millioner års siden" (... crude oil and natural gas stem from tiny animals and plants living in the oceans 150 million years ago.). The process is illustrated by naïve drawings in three steps ("cartoon") showing the sedimentation of dead plants and animals, but nothing about cap rocks, reservoir rocks or source rocks. However, these rocks are mentioned in the written text. The rest of the chapter (pp. 175-183) is about seismic, investigation, production, processing, use of oil and gas and the environmental problems coming up.

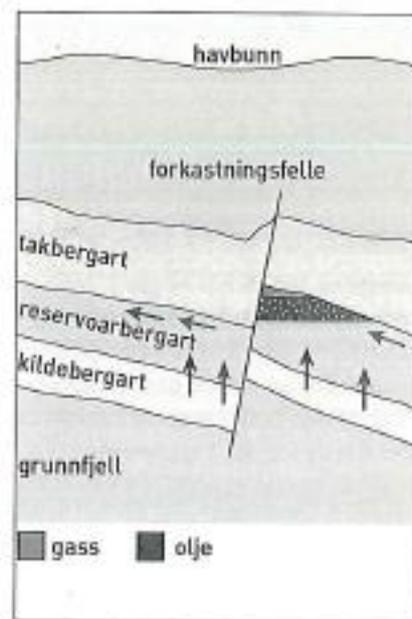


Figure 9. Eureka 10 (p. 74) Figure-Text (Author’S Translation): *Olje og gass er fanget under den skråstilte forkastningsblokken og utgjør et petroleumfelt. Olje og gass som ikke blir fanget opp i forkastningsfellen, går til en annen felle eller forsvinner til overflaten* (Oil and Gas are Trapped under the Inclined Dislocation Block and Forms a Petrol Field. Oil and Gas not Trapped in the Dislocation, Moves to Another Trap or Upwards)

Words in Figure 9: *havbunn* (sea floor), *forkastningsfelle* (dislocation trap), *takbergart* (cap rock), *reservoarbergart* (reservoir rock), *kildebergart* (source rock), *grunnfjell* (bedrock), *gass* (gas), *olje* (oil).

3.3.3 Years 8-10, Geography Textbooks

Matriks 8 (p. 69). The subchapter *Avsetningsbergarter* (Sedimentary rocks) has a very short description of the process starting with: “*Olje og gass kommer fra døde plante- og dyrerester, særlig plankton*” (Oil and gas stem from remainders of plants and animals, in particular planktons), following by two-three sentences describing very superficially the rest of the process. The text is supported by a figure (p. 69) showing the different layers of rocks in an oilfield, and drilling into reservoir rocks.

Underveis 9 (pp. 176-181). The chapter *Olje og gass på den norske kontinentalsokkelen* (Oil and gas on the Norwegian continental shelf) has no description of how oil and gas have come about.

4. Discussion

If we agree with Orion and Ault (2007, p. 660) that we live in a cyclic world, it is important for pupils to get in grip with the world-view of geological systems and cycles during compulsory education. For presentation of the water cycle (Hansen, 2012), the same publishers adapted Harlen’s (2010, p. 25f) Lateral model of progression with the first simple introduction of the whole cycle at Year 3, and progression at higher level in coming years.

There are also pedagogical reasons to build systems, i.e., cognitive structures, *schemas* as Jean Piaget called them (Piaget & Inhelder, 1974), for mental operations to fit new “bits and pieces” into the systems years to come. All Harlen’s (2010, p. 25f) three models of progression, in particular the Lateral and Spiral curriculum, are hitting for a holistic view in science topics, as Ben-Zvi-Assaraf and Orion’s (2010b) STH model.

4.1 The Rock Cycle

The texts Years 1-4 about stones and rocks contains some science terms the pupils could use to explore, describe and present observations, i.e., the texts could support the pupils in reaching the general science competence aims after Year 2, but only partly after Year 4. The texts also describe land formations and use geographic names pupils could use when exploring their local landscapes. I.e. the texts could support the pupils in reaching the geography competence aims after Year 4. The texts about stones, rocks and landscape at Years 1-4 are about some of the components of the rock system, but hardly about the processes within the system [system level 0 to 1, Tables 1 and 6].

The science texts Years 5-7 describe how some minerals and rock types were formed and could help the pupils to examine some of these types from nearby surroundings, i.e., the texts could support the pupils in reaching the science competence aims after Year 7. The rock formation texts in science Years 5-7 are about organization some of the system’s components and processes within a framework of relationships. There are generalizations and examples of the dynamic relationships within the system. The science texts present some of the hidden dimensions of the system [system level 5 to 6, Tables 1 and 6].

The geography texts Years 5-7 might help the pupils to give a simple explanation of what the Ice Age meant to the formation of the local terrain and the country as a whole, i.e., the texts could support the

pupils in reaching the geography competence aims after Year 7. However, the geography texts only present a few of the components and one of the processes of the system [system level 0 to 1, Tables 1 and 6].

Despite the science competence aims after Year 10 points to plate tectonics, the texts in *Eureka 8* also are about dynamic relationships within the rock system and some hidden dimensions of the system [system level 5 to 6, Tables 1 and 6]. The descriptions and explanations are deeper than Years 5-7, because there are some links between rock formation and plate tectonics.

The geographical texts might help the pupils describing and explaining natural landscapes in their local community, i.e., the texts could support the pupils in reaching the geography competence aims after year 10. *Matriks 8* is outstanding, the only textbook presenting the cyclic nature of the system and naming it “the rock cycle”. Figure 5 makes it possible to think temporally [system level 8, Tables 1 and 6]. Compared to Figure 3, *Matriks 8*'s figure is one-dimensional (in circle). There are no direct transitions from igneous rocks to metamorphic rocks or from metamorphic rocks to sedimentary rocks. However, the text gives a comprehensive explanation of the formation of igneous rocks, sedimentary rocks, and metamorphic rocks.

4.2 The Plate Tectonic Cycle

Despite the science competence aims after Year 7 are about rock formation, the texts at Years 5-7 also contain some elements of plate tectonics. They are concentrated about some of the components of the upper visible part of the plate tectonic cycle in Figure 1 and processes within the system—and the relationships among some of the system's components [system level 1 to 2, Tables 1 and 6]. The science texts Years 5-7 could, based on plate tectonics, support pupils describing and explaining how some minerals and rock types were formed.

The science texts Years 8-10 could support pupils explaining some of the characteristics of plate tectonics and the earths changing over eons. I.e. the texts could support the pupils in reaching the first science competence aim after Year 10. The texts are more advanced than Years 5-7, both about the dynamic relationships within the system and the hidden dimensions of the systems [level 6, Tables 1 and 6]. Some textbooks show retrospection [partly level 8, Tables 1 and 6] presenting the position of the plates during the Earth's history (as “cartoons”), but no predictions. That might foster ideas of a static earth from now on (King, 2010). Years 8-10 the science textbooks had the opportunity to present plate tectonic as a holistic cycle, but only *Eureka 8* did. Without using the concept “plate tectonic cycle”, *Eureka 8* explains the main characteristics and the underpinning of the theory of plate tectonics [system level 7 to 8, Tables 1 and 6].

The geography texts Years 8-10 could help pupils explaining basic internal and external forces on earth. The texts are comprehensive, but mostly concentrated on how the forces could explain the upper part of the plate tectonic cycle [system level 6, Tables 1 and 6], i.e., the texts could support the pupils in reaching the geography competence aims after year 10.

4.3 Oil and Gas Formation

The science texts Years 8-10 could hardly help the pupils explaining or even describing how crude oil and natural gas have come about, i.e., the texts do not fully support the pupils in reaching the second science competence aim after Year 10. Some parts of the system are briefly described and sparsely illustrated at Years 8-10, best in science textbooks [system level 2 or 3, Tables 1 and 6]. No textbook show the oil and gas formation as a subsystem of the plate tectonic cycle.

Table 6. Level of Geological System Thinking in Textbooks for Science and Geography from the Two Best-Selling Publishers Aschehoug and Gyldendal

System level: from 1 low, to 8 high			
Topic: R=Rock formation, P=Plate tectonics, O=Oil and gas formation. L=landscape, ice age			
Science	System level (Topic)	Geography	System level (Topic)
Aschehoug		Aschehoug	
<i>Cumulus 1</i>	<1 (R/L)		
<i>Yggdrasil 5</i>	5 (R), 1-2 (P)	<i>Midgard 5</i>	<1 (R/L), 0 (O)
<i>Tellus 8</i>	6 (P)	<i>Matriks 8</i>	6 (P), 8 (R/L), 0 (O)
<i>Tellus 9</i>	2 (O)		
Gyldendal		Gyldendal	
<i>Gaia 3</i>	<1 (R/L)		
<i>Gaia 5N</i>	1-2 (P), 6 (R)	<i>Gaia 5S</i>	<1 (R/L)
<i>Eureka 8</i>	7-8 (P), 5-6 (R)	<i>Underveis 8</i>	<1 (R/L), 6 (P)
		<i>Underveis 9</i>	1 (P/L), 0 (O)
<i>Eureka 10</i>	(O)		

5. Conclusion

The texts cover all curricular geological competence aims National Curriculum with one severe exception in Natural Science: Oil and gas formation is superficially described, with no references to the causation by plate tectonics. If only reading the texts, it seems impossible to reach the competence aim: “explain how crude oil and natural gas have come about”. The text to rock formation, plate tectonics and landscape formation, however, could support the pupils in reaching the rest of geological competence aims.

The level of geological system thinking in the texts develops from Year 1 to 10, but seldom reach level 7: *To give the students the ability to understand the cyclic nature of the systems* (Tables 1 and 6). The presentations of plate tectonics and rock formation develop over several years, very much like a Spiral curriculum or following a STH-model. There are yearlong pauses, but the texts in the upper years lead to understanding of the dynamic relationships and parts of the hidden dimensions of the rock formation,

plate tectonics and landscape formation. The cyclic nature of the rock formation and plate tectonics are presented in only one book for each system, and would reach only a part of the pupils. Therefore it is hard to say that Norwegian textbooks for compulsory education promote full and deep geological system thinking. However, the texts for plate tectonics and rock formation are a solid base for appropriate teaching so the pupils might be able to acquire system thinking. There are some problems: Geology topics are spread over 10 years, spread on two subjects Natural Science and Geography, often taught by different teachers. These are areas that would benefit from further investigation.

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