SALTWATER DISTRIBUTION IN THE BEDROCK OF SOUTHWEST SCANIA

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Abstract

The Quaternary deposits found in the Alnarp valley in southwestern Sweden have had the greatest influence on chloride values in shallow groundwater. This is mostly due to the presence of high permeability sands that enable efficient groundwater extraction, which leads to upconing and saltwater intrusion either because the piezometric levels are near the sea level or the extraction occurs near the ocean. Highly saline fossil water has been found deep in the Scanian bedrock. The predominant hypothesis is that this fossil water was formed by a combination of sea transgression over the land during the Mesozoic era and tectonic movement, which pushed the seawater deep underground. Meanwhile bedrock with low permeability has conserved the fossil water. Weathering of the Danian limestone bedrock increases the chloride content in groundwater due to ion exchange processes. However, in this case ion exchange in the bedrock only contributes a small portion of chloride to the groundwater in comparison to fossil water. Depth is a contributing factor to high chloride concentrations found in groundwater due to the presence of fossil water, which is seldom refreshed, and therefore remains saline. The calcium:sodium ratio is much higher in the deep groundwater compared with seawater. The potassium:sodium ratio is on the other hand, much lower. The salinity increases 100 g/L TDS per 1000 meter with depth. These results can be used for assessing the risk of upconing saline water in deeper wells for irrigation and drinking water supply.

Keywords: Alnarpsströmmen, Alnarp valley, Scania, upconing, fresh-water interface.

Introduction

As a result of the geological framework of the Alnarp valley and the surrounding recharge area, it has been very beneficial to extract water from the aquifer from this area. Extensive pumping has lowered the

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groundwater pressure below originally artesian levels until 1980. Thereafter, the extraction has been reduced and the groundwater levels and pressures have been restored. From 1965, the water quality and water pressures have been controlled in a regional scale by the Alnarp Aquifer Association (see a brief description in Leander and Persson, 1999). Saline groundwater has been found in various concentrations throughout southwestern Scania. In this study, the aim is to gather hydrogeological data from various projects and interpret the findings in relation to chloride values in groundwater. The main data that has been obtained includes chloride concentration values from groundwater samples obtained up to a depth of 1900 meters. The first step in analyzing these chloride values is to understand the geology of the area. A thorough investigation of the Quaternary deposits and bedrock in southwest Scania is necessary, since they comprise the aquifers, which harbor the groundwater. The processes focused on are the possibility of saltwater intrusion and upconing, both of which may be influenced by groundwater extraction. The hydrogeological data is presented in three different scenarios to enable complete investigation of chloride concentrations in groundwater. These scenarios include studying the change in chloride concentration in relation to location, depth and geology of the aquifer.

Geology of southwest Scania

Sweden lies in the center of the Baltic Shield, which is one of the Earth's Precambrian shields, and includes Norway, Finland and a small portion of Russia. Its bedrock has developed through metamorphic processes in the Earth's crust. The studied area lies on the Baltic shield and includes a portion of southwestern Sweden in the province of Scania. Figure 1 shows the area, which is south of the border drawn between Landskrona in the northwest and Ystad in the southeast. It is along this border where the Tornquist Zone is located. The Tornquist Zone is an area of repeated movement of the continental crust and consists of faults, which extend from the Rumanian coast of the Black Sea to the North Sea in the northwest. It also forms the border of the Baltic Shield and the East European Platform in southwest Sweden (see Figure 2). The movement along the zone in Scania has created hilly ridges alternated with areas of young, thick

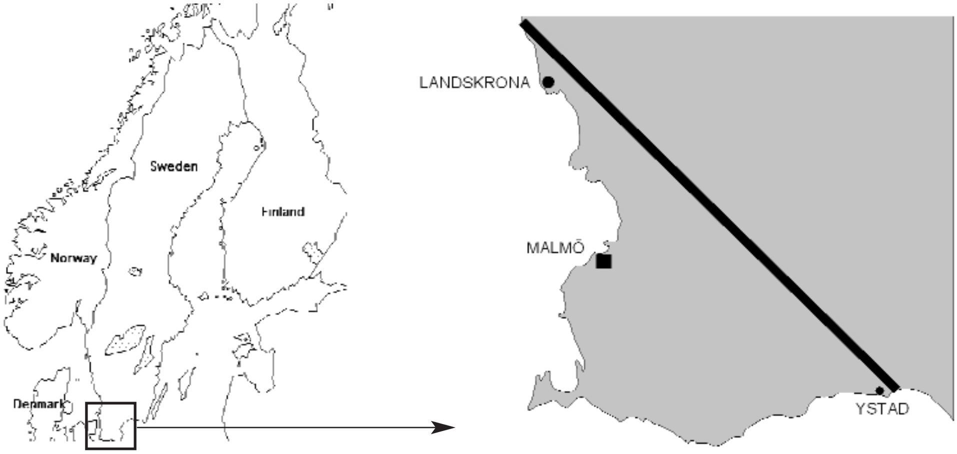


Figure 1. The location of the study area lies in southwestern Sweden, and includes all land southwest of the border drawn between Landskrona and Ystad.

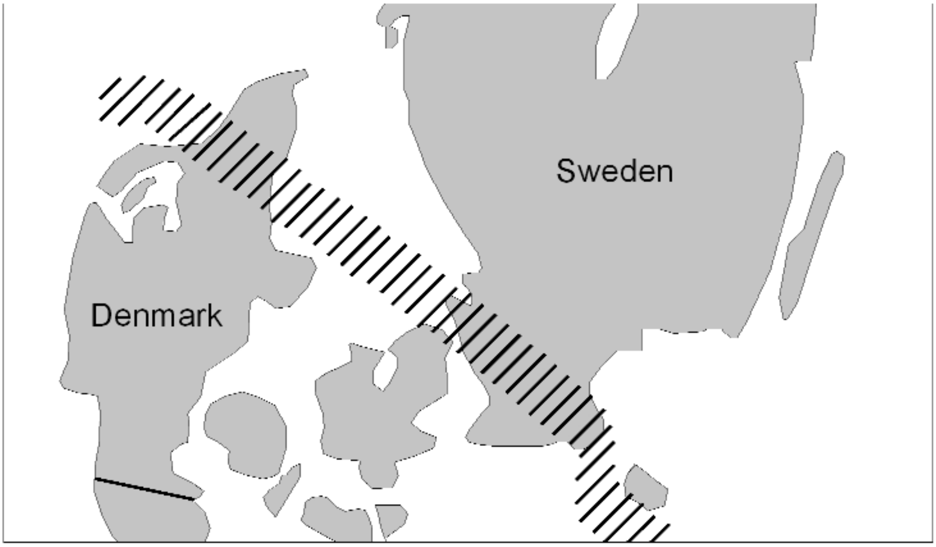


Figure 2. The Tornquist Zone is represented by the series of black parallel lines. It extends from the North Sea near Denmark in the northwest, through southern Sweden and ends at the Rumanian coast of the Black Sea (not shown).

fossiliferous strata. Dolerite dikes from the Permo-Carboniferous age are found along this zone as well as basalts from the Jurassic-Cretaceous Period. The geology southwest of the Tornquist Zone is made up of Phanerozoic sedimentary and magmatic rocks (Fredén, 1994).

Bedrock formation and characteristics

The majority of the bedrock in southwest Scania was formed during the Paleozoic era and consists of reef limestone, shale, alun shale, sandstone and conglomerate. Shale formed during the Silurian period is the most common rock found in this bedrock and was formed at great depths by a combination of erosion products and mountain-building activity (Fredén, 1994). The Romele horst is one of several crystalline horsts in Scania and lies just northeast along the Tornquist zone. The western fault and folding zone of the horst is the biggest in this region (Barmen, 1992).

There has been periodic tectonic activity in the strata, which in some cases has caused the layers to invert so that the older layers were placed on top of younger (Fredén, 1994). Tectonic activities in this area have caused uplift along the horst and tilting of the bedrock towards the southwest (see Figure 3). The uplift has enabled sedimentation and erosion to occur and has resulted in the deposition of Cambrian and Silurian rocks. These deposits form the upper bedrock surface within narrow, NW-SE oriented belts in the vicinity of the horst (Barmen, 1992).

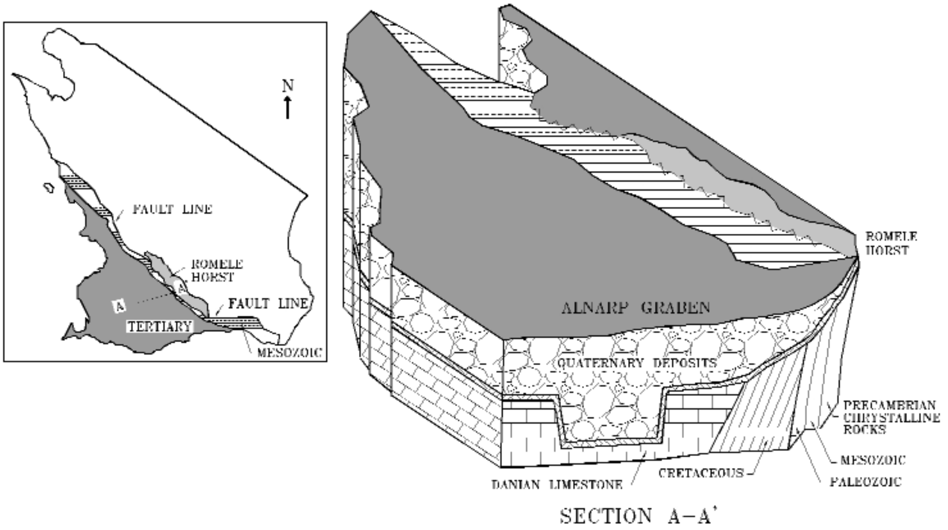


Figure 3. Cross section A-A' shows Quaternary deposits and bedrock from southwest to northeast in southwest Scania. The northeastern section ends at the Romele horst, an area where uplift occurs due to tectonic activity. From Fredén (1994).

The uplift also caused the main part of the horst to be raised above younger sediments during the Cretaceous and Tertiary. This caused Triassic, Jurassic and Cretaceous sedimentary rocks to be steeply tilted southwest of the horst. Table 1 shows data from a 3700 m deep borehole east of the city of Lund where the tectonic activities at the Romele horst have had an effect on the Quaternary layers between the Upper Triassic and the Cretaceous. During the time of uplift, the Cretaceous layer was pushed down, enabling the Triassic layers to rise. A visible picture of this is shown in Figure 4, which shows how the bedrock under the Alnarp valley has been pushed down while that at the Romele horst, has been pushed upwards. During these activities, fossil water with lower salt concentrations was pushed down with these layers, while more saline water was lifted up. The restoration of salt gradients continues still.

The sedimentary rocks formed during the Cenozoic era are considerably thin. They consist of the Danian limestone, which forms the surface bedrock in southwest Scania, and is no more than 65 meters thick. Occasionally it is covered by younger sedimentary rocks (Fredén, 1994). Limestone is mostly made of calcite, but contains also strontium and magnesium. The Alnarp depression was formed about 60 million years ago during the Tertiary period and stretches along the Tornquist zone from Landskrona to Ystad. It is a valley about 50 km long, 5 km wide and about 100 m deep. The exact cause of its formation remains unknown. However, it is speculated that the valley was formed by tectonic movement since it forms a rather straight, narrow cut into the earth and is located on the Tornquist zone, which is an area known for repeated movement and faulting. The Alnarp valley has been filled and emptied by glaciers during the ice ages. The melt water from the glaciers distributed sand and gravel deposits along the valley and across the Scania region.

Table 1. Geological data from Lund geothermal project.

CHRONOSTRATIGRAPHY				LITHOLOGY
SYSTEM	SERIES/STAGE	DEPTH (m)	THICKNESS (m)	FORMATION
Quaternary		47	47	
UPPER CRETACEOUS	Campanian	211	164	HÖLLVIKEN
	Santonian			
	faulted zone	223	12	
LOWER JURASSIC	Pliensbachian		63	RYA
		286	140	
	Sinemurian	390	58	
		525	77	
	Hettangian	1060	535	HÖGANAS
UPPER TRIASSIC	Rhaetian	1117	57	
		1200	83	
	Norian-Carnian	1310	110	KÅGERÖD
	Rhaetian	1425	115	HÖGANAS
CRETACEOUS U	Campanian-Santonian	1531	106	HÖLLVIKEN
L	Valanginian-Ryazanian	1946	415	Unnamed formations
				ANNERO
PRE CAMBRIAN with PERMO-CARBONIFEROUS DYKES	faulted zone	2050	104	Gneiss with zones of L. Cret. Rocks
		2765	715	Gneiss, metabasite and NW dolerite
		3154	389	Banded gneiss, gneiss, granite, metabasite and NW dolerite
		3182	28	Quartz-riched granitoid
		3202	20	"Quartzite Charnokite?"
		3577	375	Granite, metabasite, gneiss-granite and NW dolerite
		TD 3701.8	125	Banded gneiss, gneiss-granite, metabasite and NW dolerite

From Andersson (1982).

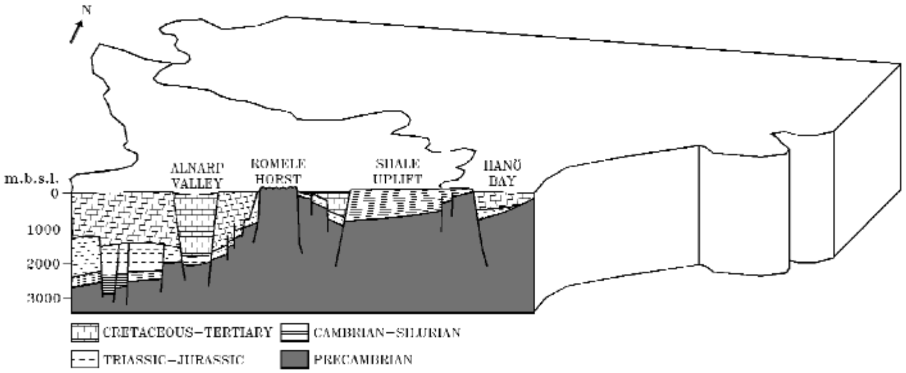


Figure 4. Cross section of the Scanian bedrock showing inverted layers and areas of faulting. From Fredén (1994).

Quaternary deposits

The Quaternary deposits in southwest Scania are on average between 40 and 60 meters thick, those along the Alnarp Valley being the deepest. During the periods when the glaciers retreated from the Swedish landscape and the sea level was relatively low erosion occurred and coarse materials such as sand and gravel were deposited (see Figure 5). Many of these sediments then became covered by marine clays (Appelo and Geirnaert, 1991). Therefore, the Quaternary deposits of Southwest Scania are made up mostly by clayey till, but they also include small areas where glaciofluvial deposits, clay-silt and till are found. The map of Quaternary deposits in Figure 5 shows that the region along the Alnarp depression is mostly covered in glaciofluvial sediments, also known as Alnarp sediments. They are usually situated directly on the bedrock surface. However, here and there till is found between the Alnarp sediments and the bedrock (Barmen, 1992). The local bedrock is often the main component of a glacial till Quaternary deposit, even if it does not fully determine the composition (Barmen, 1992).

Therefore, southwestern Scania, with bedrock of limestone and shale that is easily eroded by glaciers to a very fine-grained product, has a soil cover predominantly of clayey till and clay till with a high content of lime (Nilsson and Gustafsson, 1967). The sediments tend to become more fine-grained in the northwestern direction of the Alnarp valley (Barmen, 1992). These have been assumed to have been deposited by a large river that once flowed from the southeast into the Alnarp depression (Holst, 1911; Nilsson, 1959, 1973).

Groundwater quality

Water quality is determined by the solutes and gases dissolved in the water, as well as the matter suspended in and floating on the water. One basic measure of water quality is the total dissolved solids (TDS), which is the total amount of solids, in milligrams per liter that remains when a water sample is evaporated to dryness. Water naturally contains several different dissolved inorganic constituents, which constitute the bulk of the mineral matter contributing to TDS (Fetter, 2001).

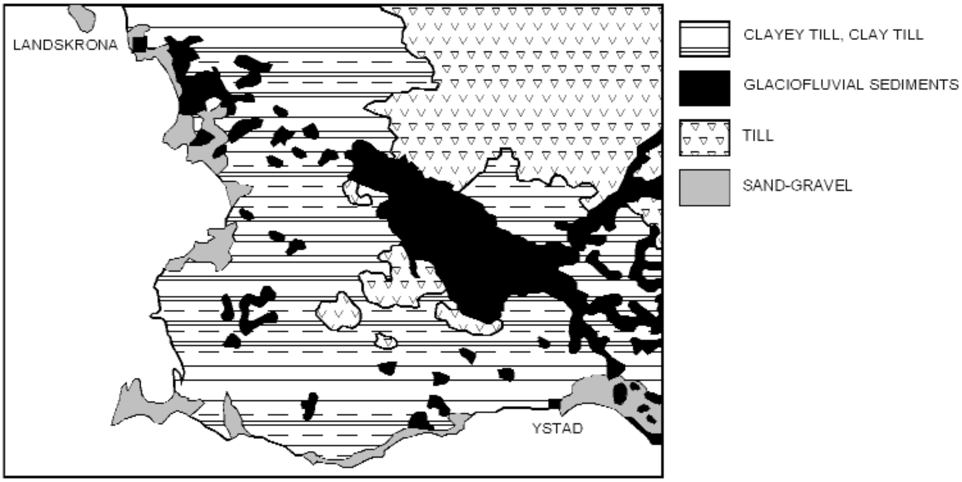


Figure 5. Quaternary deposits found in southwest Scania. From Fredén (1994).

These constituents are major cations: calcium, magnesium, sodium and potassium, and also major anions: chloride, sulfate, carbonate and bicarbonate. Minor constituents, trace elements and dissolved gases may also cause groundwater contamination but will not be a focus in this study.

Many aquifers in southwestern Scania contain fresh and salt water, mainly due to the presence of fossil water. Weathering of the calcium-rich limestone bedrock encourages ion exchange processes and increases the amount of chloride in groundwater. However, weathering is not a main cause of highly saline water in southwest Scania. In these aquifers, the salt water falls beneath the fresh water due to its higher density. Upconing occurs when an aquifer contains this scenario of fresh water overlying salt water and groundwater is pumped at rates, which cause the salt water level at the pump, to rise and possibly be extracted with the fresh water. Saltwater intrusion occurs when fresh water is diverted from the aquifer, yet the hydraulic gradient in the aquifer still slopes toward the salt water/fresh water boundary. The saltwater boundary will slowly move inland until it reaches an equilibrium position based on the new discharge conditions. Saltwater intrusion occurs mostly in cases where groundwater resources are being developed and is often accompanied by cation exchange processes, which causes an increase in calcium content in groundwater. If cation exchange does not occur then the salt will remain as mainly NaCl. This will cause an increase in the amount and concentration of sodium and chloride ions in groundwater.

The amount of groundwater that can be extracted from an aquifer in a certain amount of time is called the exploitation potential. The exploitation potential is affected mostly by the permeability of the aquifer material and the amount of water flowing into the aquifer. The groundwater yield from the limestone bedrock is mainly dependent on the degree of fracturing (Barmen, 1992). Figure 6 shows the exploitation potential in aquifers at different locations throughout southwest Scania. The Alnarp valley is the area with the highest groundwater exploitation potential of 25 L/s.

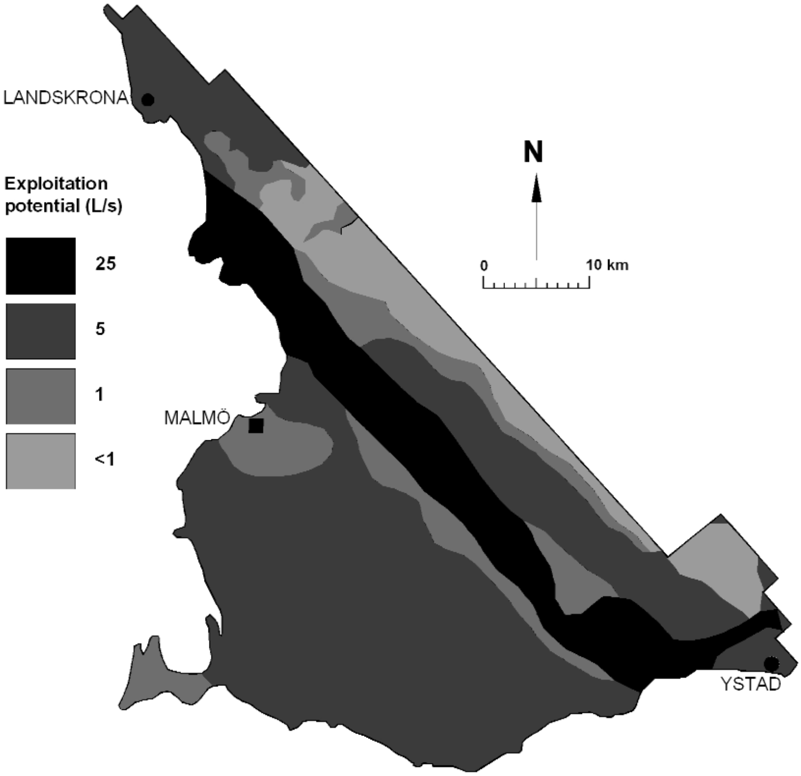


Figure 6. Groundwater exploitation potential in bedrock and Quaternary deposits shows that the highest potential is located along the Alnarp Valley between Landskrona and Ystad. From Fredén (1994).

This is because the main sediments overlying the valley are glaciofluvial sand and gravel deposits, which generate highly permeable soil. The rest of southwest Scania, which is covered mostly by clayey till and sedimentary rocks, is moderately exploitable with a potential of about 5.6 L/s. Underneath the surface rocks lies the bedrock, which is made up of chalky Danian limestone. Limestone is productive as a geological layer in an aquifer as it encompasses groundwater of fairly good quality and has a high yield (Fredén, 1994).

Figure 7 shows the piezometric levels of groundwater throughout southwest Scania. The piezometric values decline as they reach the ocean, which signifies that groundwater flows towards the sea where it is discharged. The map also shows that the gradient of the piezometric levels is steeper around the Alnarp valley region in the northwest and southeast. This means that the hydraulic gradient is greater in these areas; thus groundwater may flow at higher velocities depending on the properties of the aquifer material. The low values that appear farther inland enable low piezometric levels (particularly in the northwest part of the valley) to appear at or below zero, far before they reach the coastline. This means that groundwater extraction near the sea could cause saltwater intrusion since they lie at sea level. The areas with greater distance between piezometric levels means the water table is more flat. This may be due to a karstic region in the limestone with flat tunnels or bedding planes.

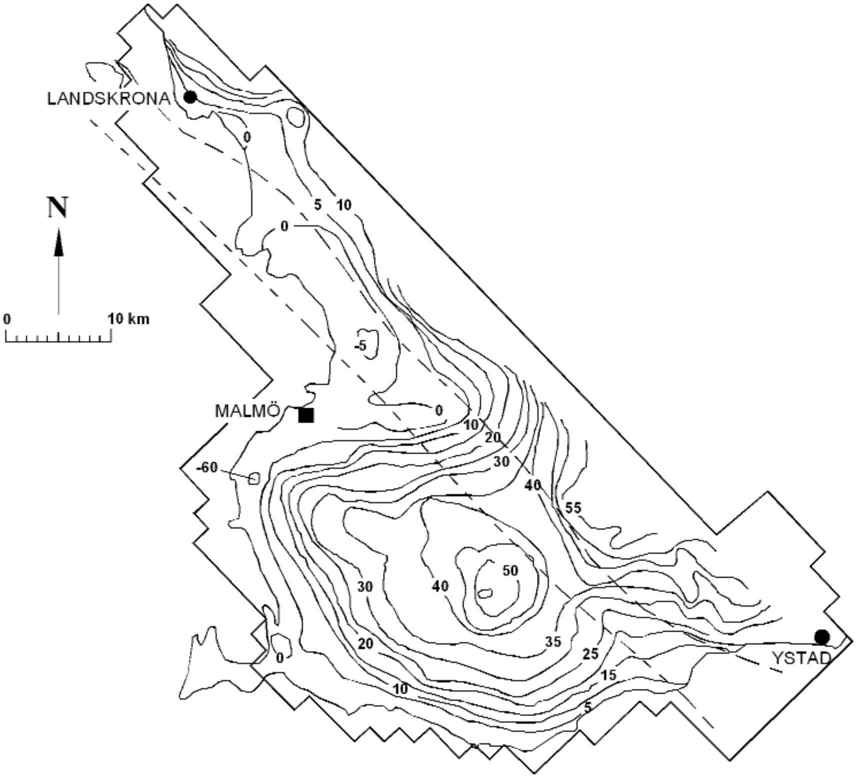


Figure 7. Potentiometric map showing the situation of the main aquifer during the year 1970. The Alnarp valley region is surrounded by dashed lines. Values are given in meters above sea level. From Barmen (1992).

Hydrogeochemical data

Analyses in the Quaternary aquifers in southwest Scania show the existence of saline groundwater. The cause is speculated to be a result of recent recharge and fossil salt water (Barmen, 1992). The recharge is thought to have occurred due to recently intruding seawater, while the fossil water was retained in older rock formations (Barmen, 1992). These incidents most likely occurred during the periods when the sea level rose over the Swedish landscape 200 million years ago during the Mesozoic era and was trapped with rocks that were pushed deeper underground.

Hydrochemical data has been collected from areas throughout southwest Scania from Quaternary aquifers. Figure 8 shows a map of southwest Scania with numbers and locations that correspond to the groundwater data that have been collected since at least 1965 (See Table 2). The Alnarp valley area is surrounded by dashed lines. The location with the highest chloride concentration is shown at point 15, which lies in the northwestern part of the Alnarp depression. The high chloride concentration at this point correlates with the location in an area previously noted to have a very low piezometric level, between 0 and –5 masl.

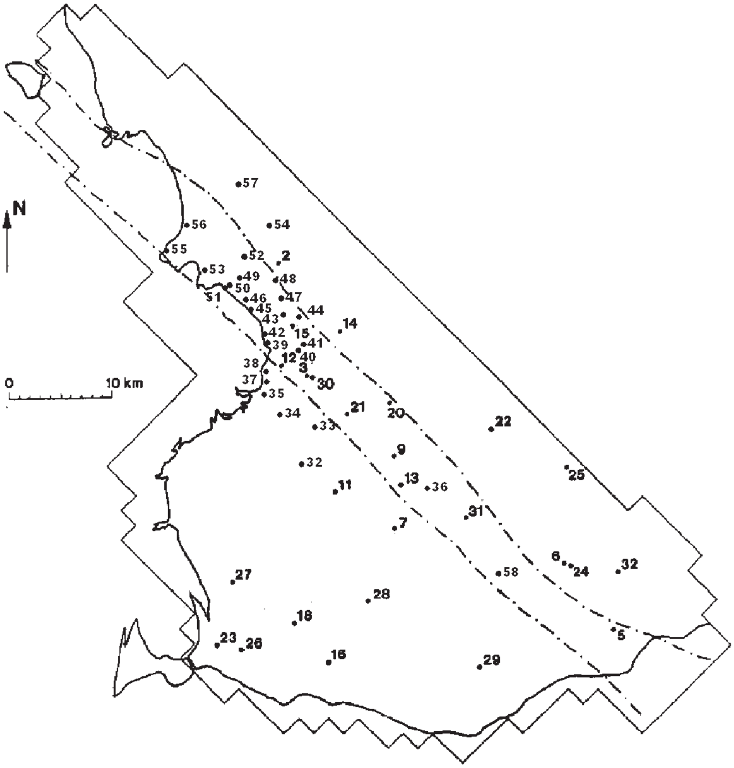
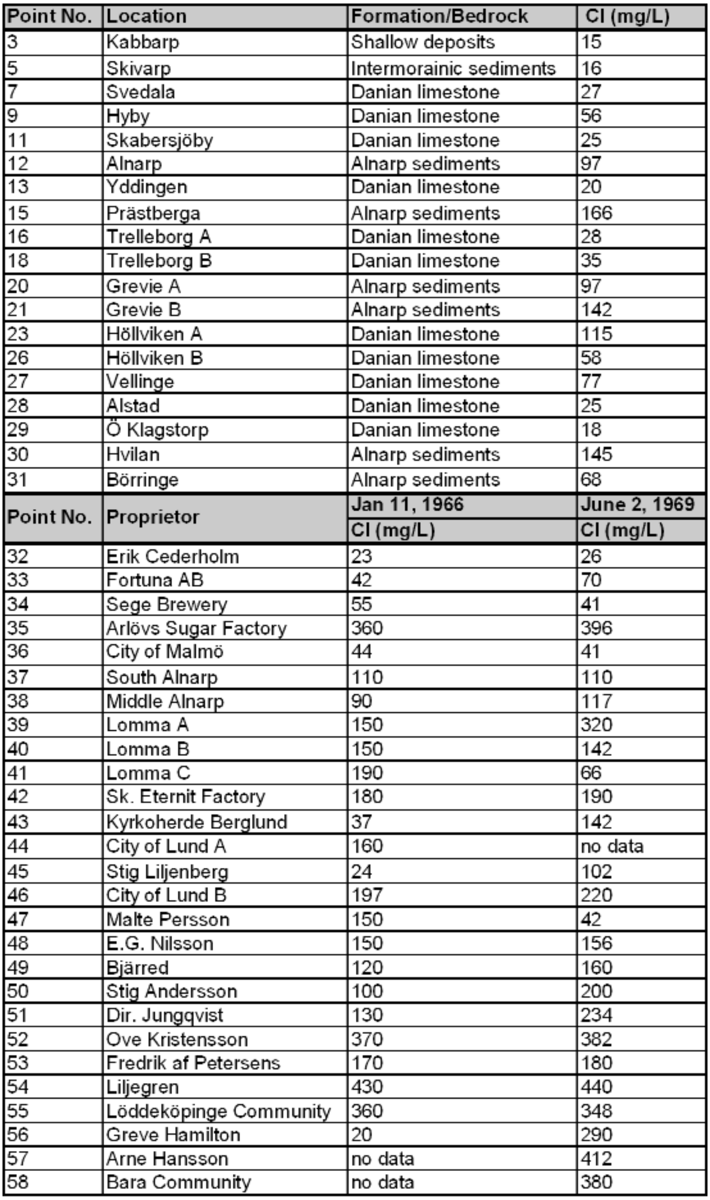


Figure 8. Locations and site number of wells throughout southwest Scania where groundwater data has been collected. The Alnarp valley is shown in dashed lines. From Barmen (1992) and Brinck and Leander, (1969).

This means that the area surrounding point 15 may be sensitive to groundwater extraction in that upconing may occur and lead to salt water intrusion in the aquifer. These results form a trend in which groundwater samples taken from the Alnarp sediments show higher chloride concentrations than other areas. In the shallow aquifer from 0 to –60 m, the Alnarp depression has generally 25 and 50% higher chloride concentration values than other parts of the limestone aquifer in southwestern Scania.

Some reasons for the high chloride values in the Alnarp depression may be due to the high permeability of the glaciofluvial sediments, since the area receives inflowing water rather easily. Thus it can increase the weathering effect on the limestone in the aquifer and increase the amount of chloride in groundwater. Historical overextraction of groundwater in the Alnarp valley may also have caused upconing or salt water intrusion into the aquifer. The river that once flowed through the valley may have had an affect since it ended in the northwestern part of the valley (Barmen, 1992). In the estuary, salty water may have markedly increased the amount of sodium ions attached to sedimented particles and caused a strong increase in the total sodium concentration at this location. A final explanation to the higher chloride values in the Alnarp valley may be that the deep cutting of the glaciers and the flooding of sea water over the land during the Mesozoic era may have allowed salty water to intrude to greater depths along the valley than in the surrounding flat lands. Also, salty water may have been pushed down even deeper due to tectonic shifting.

Table 2. Chloride concentrations, location and type of bedrock in relation to point locations shown in Figure 9.



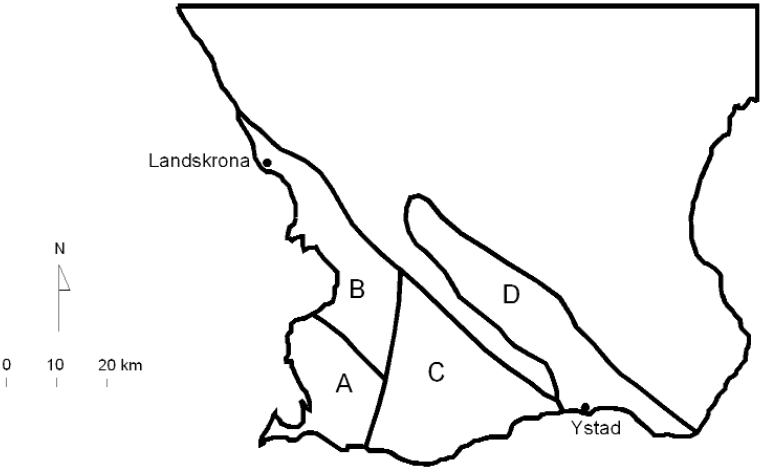
Point No.	Location	Formation/Bedrock	Cl (mg/L)
3	Kabbarp	Shallow deposits	15
5	Skivarp	Intermorainic sediments	16
7	Svedala	Danian limestone	27
9	Hyby	Danian limestone	56
11	Skabersjöby	Danian limestone	25
12	Alnarp	Alnarp sediments	97
13	Yddingen	Danian limestone	20
15	Prästberga	Alnarp sediments	166
16	Trelleborg A	Danian limestone	28
18	Trelleborg B	Danian limestone	35
20	Grevie A	Alnarp sediments	97
21	Grevie B	Alnarp sediments	142
23	Höllviken A	Danian limestone	115
26	Höllviken B	Danian limestone	58
27	Vellinge	Danian limestone	77
28	Alstad	Danian limestone	25
29	Ö Klagstorp	Danian limestone	18
30	Hvilan	Alnarp sediments	145
31	Börringe	Alnarp sediments	68

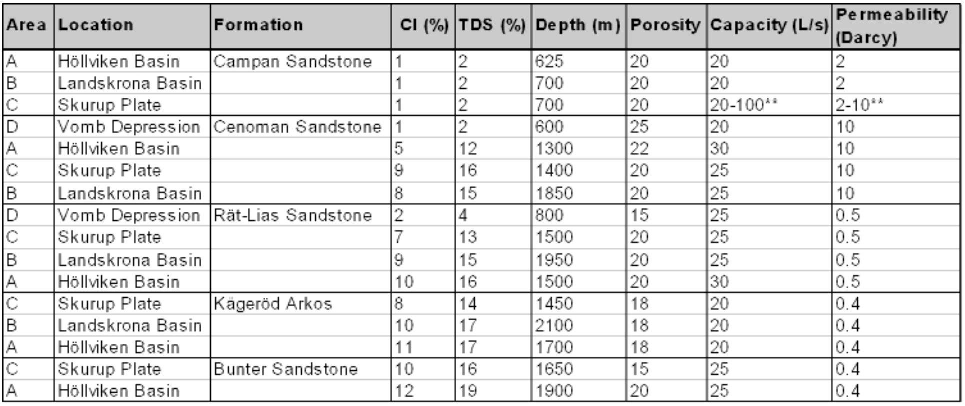
Point No.	Proprietor	Jan 11, 1966	June 2, 1969
		Cl (mg/L)	Cl (mg/L)
32	Erik Cederholm	23	26
33	Fortuna AB	42	70
34	Sege Brewery	55	41
35	Arlövs Sugar Factory	360	396
36	City of Malmö	44	41
37	South Alnarp	110	110
38	Middle Alnarp	90	117
39	Lomma A	150	320
40	Lomma B	150	142
41	Lomma C	190	66
42	Sk. Eternit Factory	180	190
43	Kyrkoherde Berglund	37	142
44	City of Lund A	160	no data
45	Stig Liljenberg	24	102
46	City of Lund B	197	220
47	Malte Persson	150	42
48	E.G. Nilsson	150	156
49	Bjärred	120	160
50	Stig Andersson	100	200
51	Dir. Jungqvist	130	234
52	Ove Kristensson	370	382
53	Fredrik af Petersens	170	180
54	Liljegren	430	440
55	Löddeköpinge Community	360	348
56	Greve Hamilton	20	290
57	Arne Hansson	no data	412
58	Bara Community	no data	380

From Barmen (1992) and Brinck *et al.* (1969).

Effects of depth on chloride concentration

Data retrieved from Andersson (1982) shows the change in percentage of total dissolved solids (TDS) and chloride in groundwater in four different locations and with varying bedrock formations (see Figure 9 and Table 3). This data includes the area and location where the analysis was performed, the type of formation surrounding the aquifer as well as the percentages of chloride and TDS, depth and porosity.





Area	Location	Formation	Cl (%)	TDS (%)	Depth (m)	Porosity	Capacity (L/s)	Permeability (Darcy)
A	Höllviken Basin	Campan Sandstone	1	2	625	20	20	2
B	Landskrona Basin		1	2	700	20	20	2
C	Skurup Plate		1	2	700	20	20-100**	2-10**
D	Vomb Depression	Cenoman Sandstone	1	2	600	25	20	10
A	Höllviken Basin		5	12	1300	22	30	10
C	Skurup Plate		9	16	1400	20	25	10
B	Landskrona Basin		8	15	1850	20	25	10
D	Vomb Depression	Rät-Lias Sandstone	2	4	800	15	25	0.5
C	Skurup Plate		7	13	1500	20	25	0.5
B	Landskrona Basin		9	15	1950	20	25	0.5
A	Höllviken Basin		10	16	1500	20	30	0.5
C	Skurup Plate	Kägeröd Arkos	8	14	1450	18	20	0.4
B	Landskrona Basin		10	17	2100	18	20	0.4
A	Höllviken Basin		11	17	1700	18	20	0.4
C	Skurup Plate	Bunter Sandstone	10	16	1650	15	25	0.4
A	Höllviken Basin		12	19	1900	20	25	0.4

**The higher values pertain to a strip of land located between Landskrona and Lund.

Figure 9, Table 3. The study area is divided into four main geological sections A, B, C and D. Table 3 shows results from analyses of geothermal pumping tests, revealing the change in chloride percentage, total dissolved solids (TDS) porosity, pumping capacity and permeability with depth From Andersson (1982).

From Figure 9 it is clear that the percentage of both total dissolved solids and chloride concentration increases with depth. It also shows that low permeability formations conserve more saline fossil water than high permeability formations. This becomes clear when comparing, for instance, the Kågeröd arkos with the Cenomanian sandstone in the Höllviken basin. However, this will be further discussed in the next section. Also, the values indicate that older formations that have been lifted up, due to tectonic movements, bring more salty and fossil water to the upper layers. Even 60 million years after the lift, the salt distribution is disturbed. This becomes clear when comparing, for instance, the Cenomanian sandstone of the Skurup plate with the Rät-Lias sandstone of the same plate.

The slow salt transport may also be due to aquitards. Results from an observation well in Lomma (well no. 3:7) were used to show a general trend in saltwater analyses in deep aquifers. The measurements of chloride content showed a clear increase in concentration of about 4000 mg/l between 90 and 110 meters of depth (see Figure 10). This reveals the existence of a saltwater front, which may exist because of geological boundaries. This water is most likely fossil water, which was trapped with the geology when the bedrock was pushed underground.

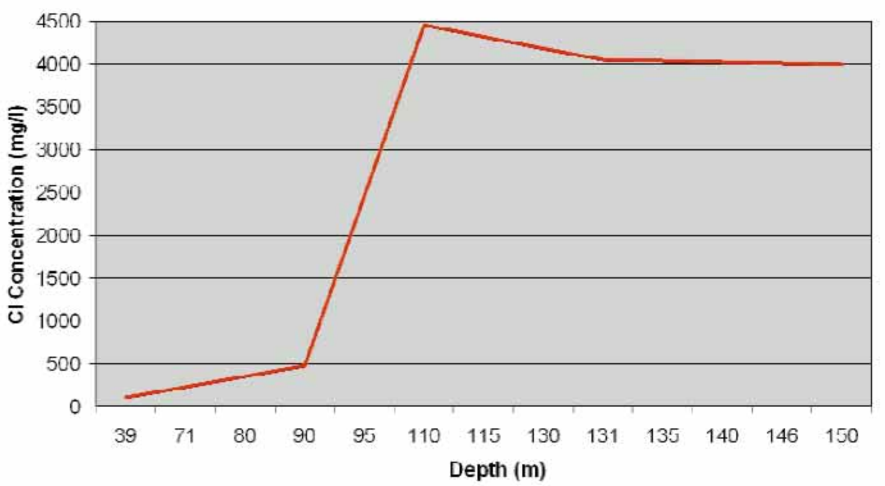
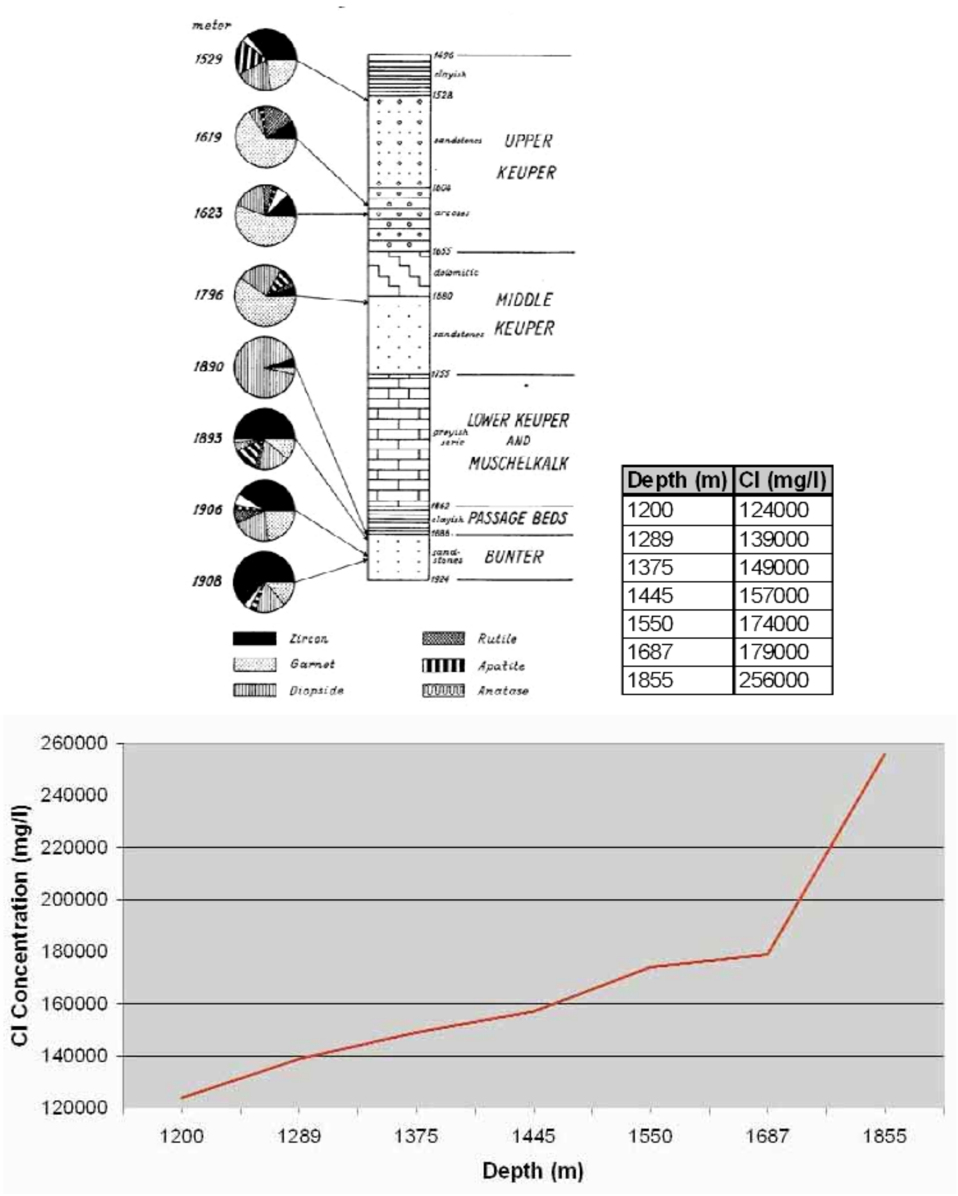


Figure 10. Groundwater samples taken from well 3:7 in Lomma show the increase in the chloride concentration with depth. From Brinck and Leander, (1975).

A drilling project at Höllviken was performed to 1923 meters below the ground surface. For a complete geological analysis of the layers of strata at Höllviken please refer to Brotzen (1944; 1949). According to Brotzen (1949), the profile of the stratigraphy and the chloride values at various depths at Höllviken is as shown in Figure 11. Results from this project show that the chloride concentration values increase constantly with depth except for the last 200 meters, where the slope of the increase in chloride concentration increases. At depths greater than 1600 m, it is most likely that high chloride values in an aquifer are due to saline fossil water.

Effects of geology on chloride concentration

The amount of chloride in groundwater throughout southwest Scania is not only due to the location and depth of the aquifer, but also it is controlled by the geology which surrounds it. Figure 9 showed that the bedrock of southwest Scania is mostly made up of Campanian, Cenomanian, Rät-Lias, Kågeröd and Bunter



Depth (m)	Cl (mg/l)
1200	124000
1289	139000
1375	149000
1445	157000
1550	174000
1687	179000
1855	256000

Figure 11. Geological data from Höllviken shows the layers of bedrock, depth and a corresponding graph of the rise in chloride concentration. The chloride concentrations at certain depths are shown in the table. From Brotzen (1949).

sandstones. Figure 12 shows the permeabilities of these sandstones and the chloride concentrations found in groundwater surrounding each formation. It is worth to notice that the chloride concentrations tend to rise where geological layers have lower permeabilities. This is because the more dense materials allow

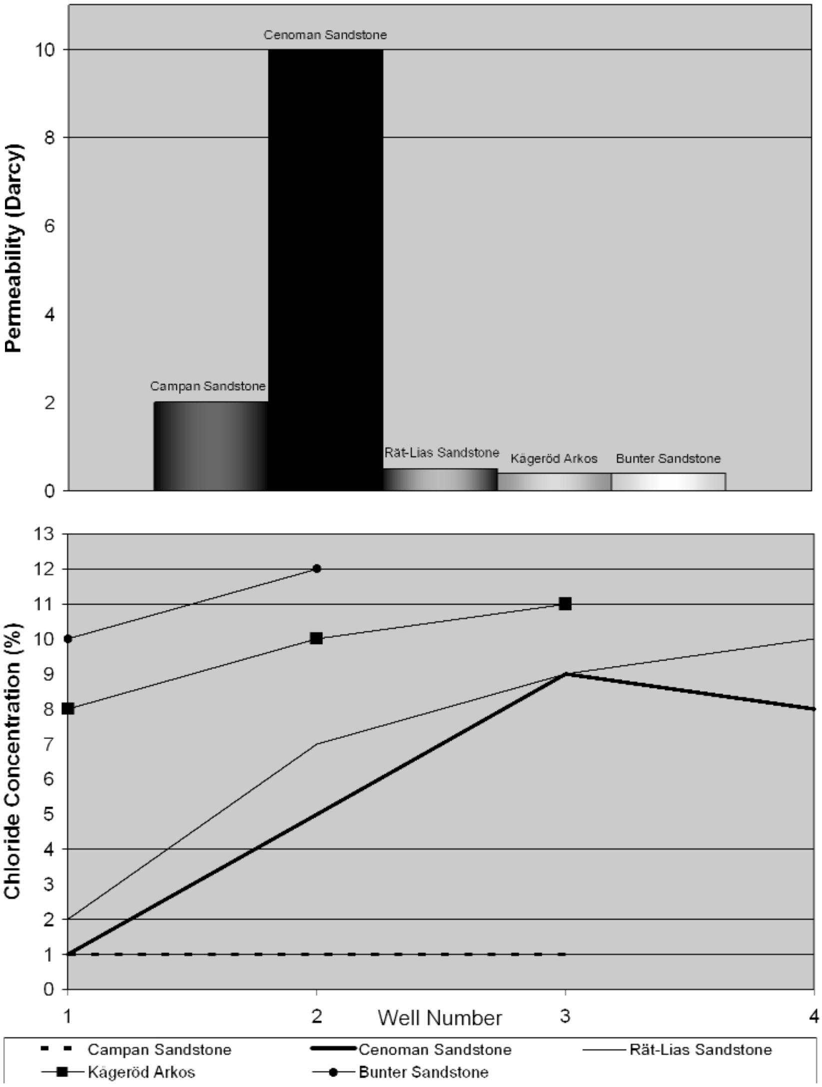


Figure 12. Permeabilities of the five main Scanian sandstones and chloride concentrations found in each layer at various observation wells. From Andersson (1982).

more surface area for cation exchange to occur, which increases chloride concentrations. Also, the more permeable a geological unit is the more possible it is for advection to occur. This might allow salt water to pass through and allow flushing, which lowers the chloride concentrations.

Figure 13 shows the four main sandstones for areas A, B, C and D, and their reported chloride values with depth. Area A is the same area from which the chloride values from Figure 11 were taken. According to Figure 13, the Bunter sandstone lies at the greatest depth, between 1700 and 1900 meters. Bunter sandstone has the lowest permeability of the four main sandstones units, which disables any flushing of saline water to occur. This correlates with the sharp peak in Figure 11 (which also occurs between 1700 and 1900 meters depth) where the chloride concentration rises dramatically.

It is worth to notice that in area C, the chloride concentration values actually decrease between 1300 and 1500 m. This can be explained by recalling in Table 1, which showed the shifting of the Cretaceous and Triassic plates, where the less saline Cretaceous layer was pushed down between 1425 and 1531. This shows that fossil water was shifted with the movement of the Cretaceous and Triassic plates.

The Cenomanian sandstone in area D has been shifted upwards to a shallower depth. Note that it shows the same chloride concentration as the Campanian sandstone, even though the Cenomanian sample originates from a deeper, more saline area. Due to the relatively high permeability of the Cenomanian sandstone, flushing occurs fast enough so that it has the same percentage of chloride as the other less permeable geological layers at the same depth. These analyses of the relation between chloride concentrations in groundwater and the geological units conclude that geology does, indeed, have an affect on the salinity of groundwater, since salinity increases with depth due to the stratigraphy and its properties.

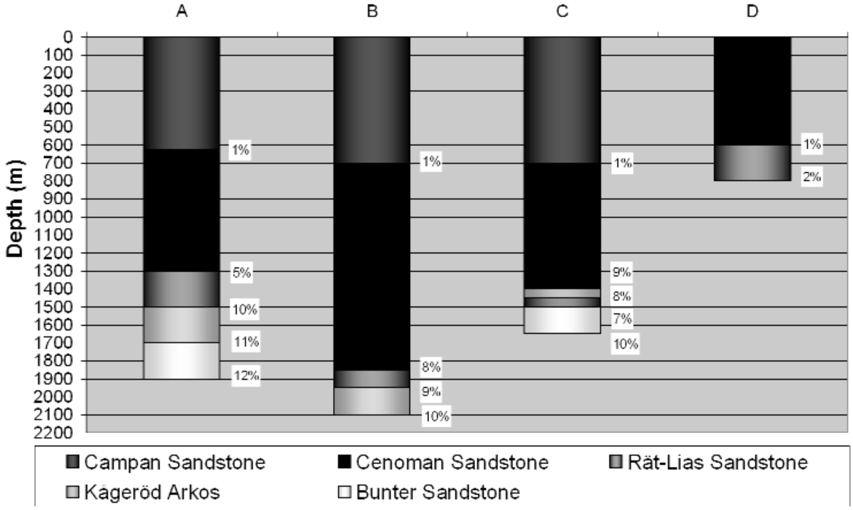


Figure 13. Geological layers and chloride concentration values(%) at increasing depth for areas A, B, C, and D, which are located throughout southwest Scania as shown in Figure 10. The legend shows the layers in order from left to right as they appear in area A from shallow to deeper depths. From Andersson (1982).

Conclusions

Geological events throughout history have shaped the Swedish landscape to the way it appears today and have had a large influence on the characteristics in the underlying groundwater. The bedrock of southwestern Scania consists largely of Danian limestone. Quaternary deposits cover the limestone, which include sand, gravel and clay. The sands and gravels are mostly glaciofluvial deposits that mainly cover the area of the Alnarp Valley. Clays cover a majority of southwestern Scania, which includes most of the areas southwest of the Alnarp valley.

Groundwater samples taken from different wells throughout the area and chloride values were observed and showed that the chloride values in groundwater in southwestern Scania are affected by factors such as groundwater extraction, salt water intrusion, fossil water and hydrochemical weathering. The chloride concentration values showed the highest values near the coast and in the Alnarp valley, while lower values occurred farther from the sea and outside of the Alnarp valley. This may be due to data which revealed that groundwater extraction occurred in the Alnarp valley near the coastline, where piezometric levels where low, which could induce salt water intrusion. This information, on top of the fact that the valley is covered by highly permeable glaciofluvial deposits, may be contributing factors to the high chloride concentrations.

Chloride levels also showed a increase with depth. This may be due to salt water that was trapped in rocks while being covered by new layers of earth and thus became fossil water. Other factors may be groundwater extraction, which causes upconing, and would affect the deeper layers first. The local geology shows to control the chloride concentration levels in groundwater. Areas with glaciofluvial deposits show higher occurrences of chloride in the shallow groundwater than others. In the deeper groundwater, areas containing low permeability geological layers have higher chloride concentrations in groundwater, since low permeability inhibits advection and flushing.

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