GEODIVERSITY REPORT

Shoreham Cement Works

Area Action Plan – Evidence Base Studies

Prepared for: South Downs National Park Authority

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Appendix 01: Geodiversity Report – Chalkrock Limited

1.0 Introduction

1.1 Objectives of the Report

In May 2018, SLR Consulting Limited (SLR) was commissioned by the South Downs National Park Authority (The Client) to prepare a Geodiversity Report for the site at Shoreham Cement Works Quarry. It is understood that the Client is creating an Area Action Plan to support the strategic policy in the South Downs Local Plan – Pre-submission September 2017 (the South Downs Local Plan).

This report presents a summary of the geological assessment undertaken, which comprised a desk study, site walkover, review of the geology and assessment of its importance together with recommendations for further actions.

It is already known that the quarry provides an excellent section of the Lewes Member of the chalk and one of the key purposes of the study will be assess the value of this exposure in a national and international context and how it can be preserved for research whilst balancing other interests in minimising the visual impact of the quarry workings within the SDNP and bringing as much of the site back into beneficial use as possible.

The fieldwork was undertaken in August 2018 by specialist consultant Prof. Rory Mortimore of Chalkrock Limited, who also produced the enclosed Geodiversity report.

1.2 Context

It is understood that the Client has requested six baseline studies from various providers, reflecting separate technical studies. The aim is for these studies to inform the Area Action Plan; the masterplanning and production of which will be undertaken by planning officers at SDNPA. This report presents only the results of the Geodiversity study.

1.3 Scope of Work

In order to satisfy the project objectives, the following scope of work was undertaken:

- document review to determine the availability of other geological exposures of the same strata in the South Downs area so that the value of the Shoreham cement works quarry can be put into context;
- site walk- over survey to inspect the remaining chalk faces to check their position in the chalk stratigraphy, determine their condition, scientific value and assess feasibility of access;
- The information obtained from the study has been collated into this report which includes comment on the value of the disused quarry (area D) as a Regionally Important Geological Site (RIGS). The report also comments on the need to conserve area D given the proposal to re-model the most prominent quarry faces and planting of Area D whilst enabling geo-conservation, given the scientific and educational value of the strata. Consideration has also been given to means of providing safe access to exposures considered worthy of preservation;

The Geodiversity report, as prepared by Prof. Mortimore, is presented in full at Appendix 01.

APPENDIX 1

Geodiversity Report

Chalkrock Limited

South Downs National Park

Shoreham Cement Works Upper Beeding Quarry

Geodiversity and Geoconservation

Geological Society Engineering Group led by Rory Mortimore 2002 on a two day field study at Upper Beeding Quarry, Shoreham Cement Works on Section 1 containing the Lewes Marl and Lewes Tubular Flints: this exposure is now overgrown – needs clearing and managing

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South Downs National Park Shoreham Cement Works Upper Beeding Quarry Geodiversity and Geoconservation.

Geodiversity has been defined as: *The natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landform and processes), and soil features. It includes their assemblages, relationships, properties, interpretations and systems*. Gray, M. (2004) Geodiversity: Valuing and Conserving Abiotic Nature, Wiley & Sons.

Amongst the wider services to the nation that geodiversity provides are: training, education and lifelong learning; a contribution to 'sense of place'; recreation and geo-tourism; aesthetic qualities and well-being. Developing a good understanding of the South Downs geodiversity and the services it provides also contributes to the sustainable management of natural resources (such as groundwater, brick clay, chalk for cement and gravel for aggregates) and the earth's changing natural systems (such as mitigating against natural subsidence, unstable ground, radon gas emissions and responding to climate change). It is for these reasons that the geodiversity of the South Downs should be understood, managed, developed and used for the benefit of the present generation and conserved for future generations. Shoreham Cement Works provides a unique insight into the geodiversity of the South Downs exposing as it does the classic 'White Chalk' formations that form the core of the South Downs, its materials, and diversity of past life represented by the great range of fossils recorded in the quarries. Shoreham Cement Works also provides clues to geological and climatic changes that have been responsible for forming this unique down-land landscape, vegetation and habitat.

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1. Introduction: The place of Shoreham Cement Works in the South Downs

Upper Beeding Quarry, Shoreham Cement Works, exposes the geology of the Chalk and Quaternary karst features and sediments in the core of the South Downs. It is a key 'anchor' section in the Chalk between the coastal cliffs of the Seven Sisters and the M3 Motorway cuttings at Winchester (Figure 1). The other field sections at Lewes and on the M3 cutting are now overgrown or inaccessible and the coast sections are becoming more dangerous due to faster rates of cliff collapse probably related to climate change (increasing intensity of rainfall) and to sea-level rise. As a result, Shoreham Cement Works, as well as having unique geological features, is now the one section remaining in the South Downs where the details of the Lewes and Seaford Chalk formations, their marker beds and fossils can be studied in relative safety (i.e. this geology is accessible to study and/or the key parts of the section can be readily made accessible and managed). These formations define the main escarpment and the dip slope of the South Downs and form the main aquifer for groundwater supply for communities within the South Downs catchment.

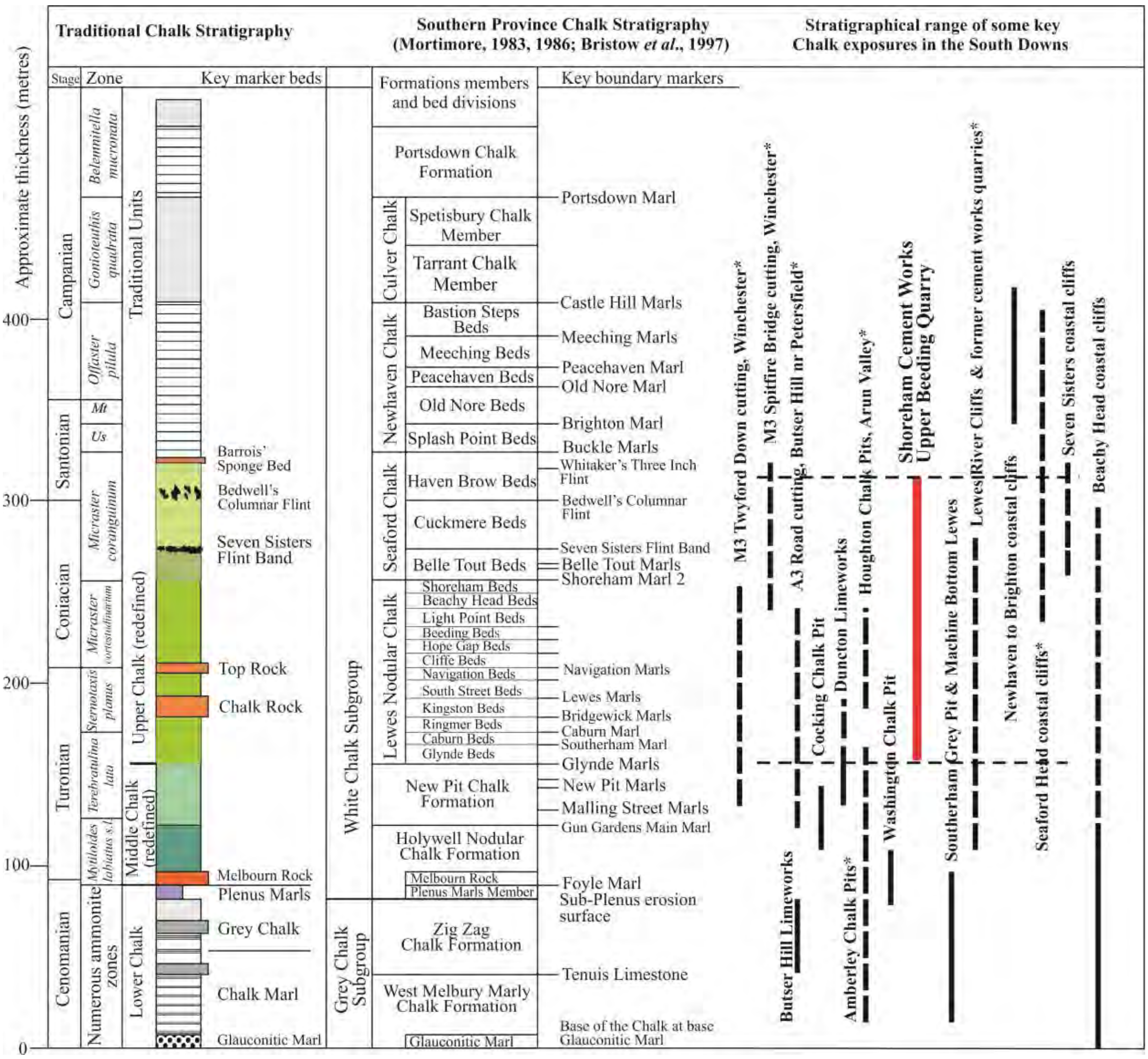


Figure 1. The place of Shoreham Cement Works Quarry in the South Downs Chalk succession compared with other field sections in the South Downs some no longer accessible (identified with an asterisk) or only partly accessible (accessible part solid line, inaccessible part dashed line).

In addition to the Chalk formations and the fossils, the examples of faults and fractures with Quaternary sediment-filled karst features and caves exposed in the quarry offer a unique insight into the deeper features controlling groundwater flow and storage in the Chalk as well as providing evidence for landscape evolution of the South Downs over the last 3 million years and identifying ground collapse hazards.

Shoreham Cement Works Quarry exposures are still accessible by following the former working roadways through areas C and D (Figures 2, 3 and 13). Some sections are overgrown by vegetation and others partly covered by scree. Scree and vegetation will continue to develop and further cover some slopes if not managed and regularly cleaned.

In contrast, other field sections in the South Downs that once exposed a succession comparable with Shoreham Cement Works are no longer accessible (Figure 1). These include the River Ouse valley former quarry exposures at Lewes (former Chalk pits at the south Portal of the Lewes A26 Cuilfail Tunnel and the Cliffe Industrial Estate former cement works quarry) which were used to establish the stratigraphy of the Lewes Nodular Chalk Formation. Other field sections on motorway or trunk road cuttings (M3 Winchester, A3 Butser Hill) are not now accessible on safety grounds. Similarly, the highest parts of the geology exposed at Beachy Head and between Beachy Head, Birling Gap and the Seven Sisters, despite having wonderful exposures, are inaccessible to study. Former chalk pits at Amberley and Houghton in the Arun River valley are either completely overgrown or provide inaccessible, vertical, old and dangerous quarry faces.

Some smaller chalk pits such as Duncton Limeworks (Figure 1) expose beds in the upper part of the New Pit Chalk Formation and lower part of the Lewes Nodular Chalk Formation, beds that are now covered by land fill in the floor of the Shoreham Cement Works Quarry Area C. The higher part of the Duncton Limeworks illustrates the problems with grading/landscaping faces as the Kingston Beds and all the marker beds once present in this part of the geology are now completely lost in the graded slopes.

2. The Geodiversity value of Shoreham Cement Works geology in a national and international context

2.1 National context

Chalk forms one of the classic landscapes of Britain and NW Europe as well as the Middle East. From the earliest studies, some curiosity driven (e.g. Mantell's 1822 Geology of the South Downs), others for practical purposes such as Neolithic flint mining, canalisation of the South Downs Rivers, lime spreading of the fields or potable water extraction have all required some knowledge of the distribution of different types of chalk and flint. Even the travellers who for centuries came to Lewes to extract the special clays as a baby's talcum powder from the Southerham Marl at Lewes (clays of volcanic origin), knew which beds provided the best sources of these clays. Ever increasing pressure from major construction projects (e.g. Channel Tunnel), urban development, groundwater resources or pollution control has required a much more detailed geology of the Chalk than was available in the 1970s. For the Chalk country of southern England detailed geological investigations in relation to these issues began in the 1970s.

Investigations in the South Downs have played a major role in developing the modern geology for the Chalk in England and field sections in the South Downs were chosen as the 'type' exposures where the Chalk formations, now mapped from the South Coast to East Anglia by the British Geological Survey, were first defined. Upper Beeding Quarry, Shoreham Cement Works, was chosen as an essential parastratotype as it exposed most of the Lewes Nodular Chalk Formation and much of the Overlying Seaford Chalk Formation, the chalks that form the core of the South Downs.

This new Chalk geology depends on recognising marker beds such as flint bands (see definition of flint and flint bands in fact files on the website www.chalkrock.com) and marl seams (thin beds made of a mixture of clay and lime) some of which have been derived from the ash falling into the chalk-sea from volcanoes like those volcanoes that erupted on Iceland causing air travel chaos (i.e. volcanogenic marls). These marls are identified as thin grey seams in the white chalk and are detected by their special chemical composition, analysed in the laboratory. Each band of flint has a unique character traceable over 1000s of kilometres across England and France including the conspicuous Lewes and Shoreham Tubular Flints. Other features of the Chalk include hardgrounds, surfaces of the chalk sea-floor that started as a chalky soup and progressively became hardened resulting in a change in chalk-sea-floor ecology from soft sediment burrowers to hard sediment borers and encrusters. Such hardgrounds are wonderfully exposed in the rock bands in Area D in Shoreham Cement Works Quarry (e.g. the Navigation Hardgrounds named after the former Navigation Pit at Lewes) and represent major ecological changes related to global sea-level fluctuations.

As in all science, the evidence for the marker beds and their continuity across the country must be testable and repeatable. The exposures of these marker beds in the South Downs, especially in Shoreham Cement Works, are now the only sections accessible for such studies where the original definitions of formations and beds can be checked and further investigations carried out as new ideas and scientific methods are developed.

2.2 Shoreham Cement works Quarry international context

The Cretaceous, of which the South Downs geology is a major part, is a very special period in the Earth's history. The demise of the dinosaurs and the rise of birds and flowering plants are part of this era. Upper Cretaceous Chalk, as a marine limestone, represents the extraordinary explosion of calcareous marine golden-brown algae (part of the plankton of oceans and seas) associated with a dramatic rise in sea-level to levels greater than 200 m above present day. The evidence for these global events is locked into the South Downs Chalk in various ways including within the diversity of fossils, chemical signals showing changes in chalk sea temperatures and salinity and volcanic ash beds. Investigations of exposures such as those present in Shoreham Cement Works Quarry contribute to our understanding of global events such as climate change and sea-level fluctuations. Studies of the fossils including the size of muscle scars in the bivalves, the abundance of sponge fossils and dirth of corals suggest marine bottom water conditions were poorly oxygenated and more acidic than typical marine bottom waters today.

From the 1970s onwards the international Subcommission on Cretaceous Stratigraphy has demanded that national groups develop a precise, bed-by-bed stratigraphy and recollect fossils in relation to this stratigraphy so that the ranges of species through the various time intervals can be accurately plotted. Each region of the world can then be compared to develop more precise time-scales and recognise migration patterns and ecological shifts. Combining this information with marine temperature curves (derived from chemical sampling sections such as Shoreham), environmental changes associated with changes in the marine fauna can be recognised. This is global multidisciplinary international Earth Science research that has led to more precise definitions of the Stages of the Cretaceous. Such work starts with detailed measured sections of the exposures at Shoreham Cement works and collection of fossils over many years. Every visit turns up something new for the UK, NW Europe or to science. Each new fossil find contributes greatly to the international effort.

As a result of the work of Mantell (1822, 1927) and Dixon (1850) many of the species of fossils from the South Downs are the 'types' for international studies. Shoreham Cement Works was not extant at the time of Mantell or Dixon and their fossil collections were not precisely located in the stratigraphy. Subsequent work at Shoreham and Lewes re-collecting the fossils has been able to fix many of Mantell's type species into a precise stratigraphy. New fossils crucial for international correlation and broader studies of Cretaceous marine biota have also been found. This on-going work makes the Chalk exposures such as those in Shoreham Cement Works invaluable.

Features of that make Shoreham Cement Works Quarry an internationally important site include:

- Finding rare fossils including ammonites such as *Bostrichoceras saxonicus* and bivalves such as *Inoceramus lusatiae* ANDERT and *Volviceramus koneni* . These fossils have been found for the first time in the Cretaceous of England (at Shoreham Cement Works),and have helped link the English Chalk to European, Pacific and North American marine Late Cretaceous successions placing this part of the UK Chalk into a global context
- Recognising the volcanic-ash derived marl seams which correlate across NW Europe derived from Atlantic mid-ocean ridge volcanoes like those on Iceland (the Caburn Marl, Bridgewick Marl 1, Lewes Marl and Shoreham Marl 2 are all of volcanic-ash origin)
- Finding the exceptionally well developed/mineralised hardgrounds (cemented/hardened Chalk-sea-floors e.g. the Kingston Beds and the Navigation Hardgrounds) at several horizons representing changes in Cretaceous global sea-levels during formation of the Chalk
- Conspicuous marker flint bands traceable throughout the South Downs and beyond to the Paris Basin, to the Grimes Graves Flint Mines in Norfolk and to the Yorkshire Wolds Chalk (e.g. Bridgewick and Bopeep Flint bands, Lewes Tubular Flints, Seven Sisters Flint Band).

Being able to place each of these finds into a precise stratigraphy aids the international work on a global correlation framework, the essential first step to evolutionary and environmental change studies.

2.3 Shoreham Cement Works Quarry and Landscape Evolution

In addition to Cretaceous geology many questions remain about the processes that have created the South Downs landscape, a landscape also present in many other parts of the world. A key problem has always been dating the geological events especially those over the last about 2 million years. No datable sediments have yet been found in the dry valleys typical of the downland. Shoreham Cement Works has cut deeply into the core of the Downs adjacent to a river valley and offers a unique opportunity to investigate the processes that have created cavities, caves and collapse caverns and associated sediments as part of the fill material in these karst features. Faults and fractures sub-parallel to the Adur River valley are filled with Quaternary sediments and represent some of the landscape forming processes that led to the evolution of the Adur River valley and the South Downs, processes which are relevant to the evolution of all the Chalk landscapes of southern England and Northern France.

3. Identification of key geological exposures in the quarry representing different facets of the geodiversity and educational value

The key geological exposures in Shoreham Cement Works Upper Beeding Quarry are identified in Figures 2, 3 and 13. Localities are divided into three groups (Table 1).

Those labelled V1 to V 4 are the main viewing points from where overviews of different parts of the Chalk succession and related geology and landscape can be seen and studied from a distance.

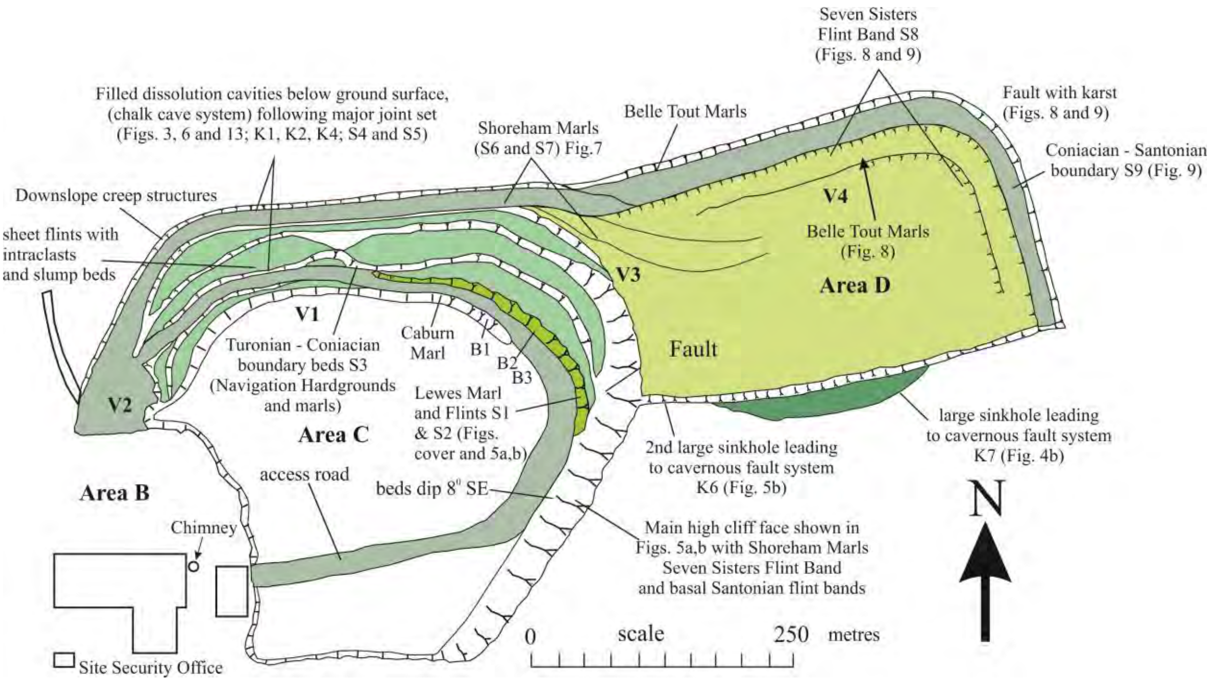


Figure 2. Plan of Upper Beeding Quarry, Shoreham Cement Works based on an original supplied by the then cement works operator, Blue Circle Industries (Figure numbers in the plan to be added).

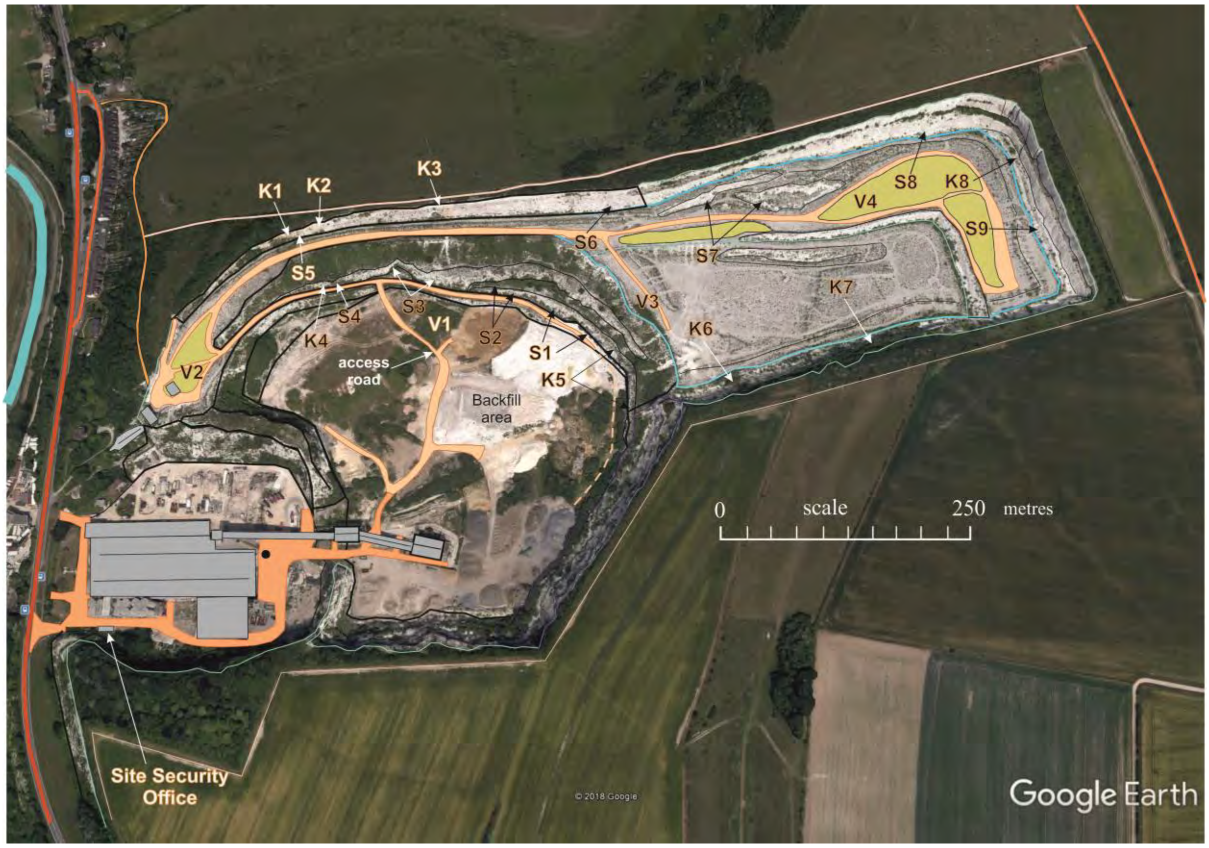


Figure 3. Plan of Upper Beeding Quarry, Shoreham Cement Works superimposed on a Google Earth image and showing localities referenced in Table 1. V=viewing point S=field section K=karst feature.

The second group of localities (S1 to S9) are the places where details of the Chalk succession, including marker beds, fossils, fractures and faults can be studied close-up.

A third group of localities labelled K1 to K8 are the places where details of the karst features including collapse caverns, coarse, crystalline calcite filled vugs in cavities formed along faults and their Quaternary sedimentary fills can be studied in detail.

Access to these exposures at present is through area B past the site security office (Figs 2 and 3) and then via a relatively new trackway cut across the landfill in area C onto the former cement works roadways close to locality V1. These roadways lead up through area C to the Top Road which then gives access to area D (Figures 2, 3 and 13). A further possible access route is via the back-road entrance from the village of Upper Beeding to the topmost roadway by the crusher plant (V2). This is the former route used by the vehicle drivers when Shoreham Cement Works was active but has now been blocked off at the former top entrance to prevent fly-tipping and unauthorised access. A new and probably safer access route could be constructed as part of developing a geology trail from the roadway along the eastern end of the quarry into area D (Figure 13).

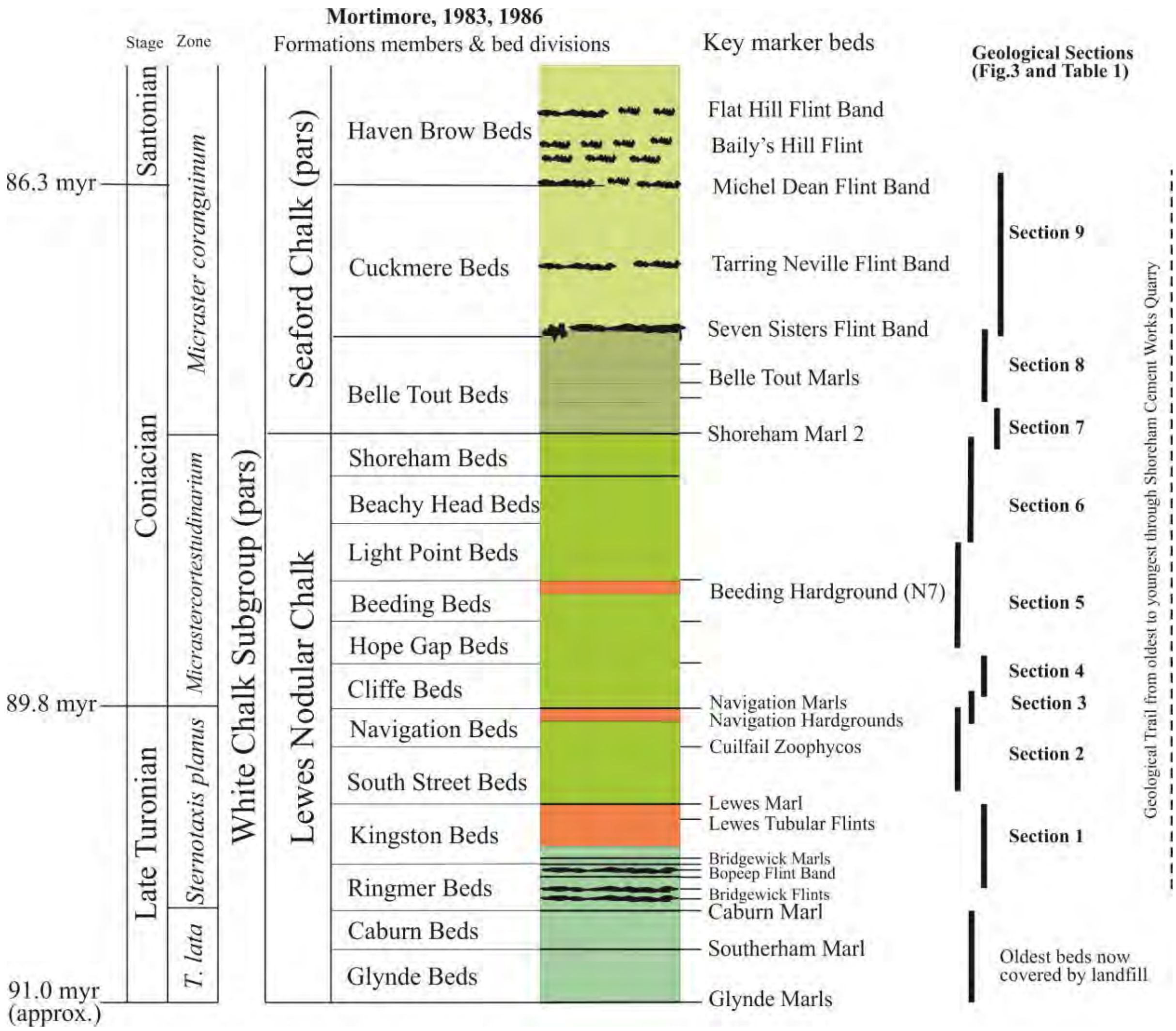


Figure 4. Schematic, simplified stratigraphical column for the Chalk in Shoreham Cement Works Upper Beeding Quarry showing the stratigraphical position of the field sections identified in Figures 3 and 13 and Table 1.

4. Recommendations on developing and managing key parts of the geological exposures including the need to conserve some vertical faces: which bits to retain and which bits could be landscaped without loss of information.

Having identified the key features of the geodiversity of Upper Beeding Quarry, Shoreham Cement Works, a discussion needs to take place so that these key features are included in any re-landscaping plan for the Quarry in both areas C and D. The Quarry was latterly worked in relatively low benches and walls to meet the safety controls required by HSE and the Mines and Quarries Act at that time. The highest Chalk faces in Area C pre-dated these requirements.

Current back-filling is taking place in Area C and is potentially going to cover the lowest exposures in the oldest Chalk geology. It should be possible, however, to retain access to Section 1 along the old quarry roadway especially in the area with the Lewes Marl, the Lewes Tubular Flints and the underlying Bridgewick Marls and flints in quarry faces that are not beneath the highest cliffs. It should also be possible to retain a view of the fault with the former waterspout at locality K5 from the top of any landfill in Area C.

The highest cliff face on the eastern side of Area C provides a spectacular view of the entire Chalk succession from the Navigation Hardgrounds in the Lewes Nodular Chalk to the conspicuous flint bands at the Coniacian – Santonian boundary in the Seaford Chalk Formation. Will this view be retained? It is currently a refuge for nesting birds including raptors. There should be no public access to the top and base of the cliff.

Sections S1 to S4 are along the former working quarry lower roadway in area C in relatively low cliff faces (Figures 2, 3 and 13). It should be possible to enhance (by clearing some vegetation and cleaning slopes) and control slope stability (local trimming and rock bolting) in this area so that access to study this geology can be retained.

Along the top road and into Area D imaginative landscaping should make it possible to retain key exposures showing the karst features (K1 to K4) and retain parts of the exposures in sections S5 to S9. Grading slopes to low angles destroys the geology, retaining some steeper slopes is essential if the geodiversity is to be conserved and made available as an educational and research resource for the future.

5. Recommendations on developing a geological trail linking the geological exposures in a history of the Earth over the last 90 million years

Starting at Viewing Point V1 a geological trail (Figure 13) from Section S1 in Area C along the lower roadway to viewing point V2 and then along the top roadway to Section S9 in Area D would take visitors through approximately 7 million years of Chalk history from 90 million years ago to 83 million years ago and the through geology representing the last 5 million years of landscape evolution creating the South Downs. A schematic geological timescale of events for the London Basin area (Figure10) and the Weald of Sussex (Figure11) illustrates the huge time gaps in the geology, without rocks, caused by various stages of uplift and erosion. The absence of rocks between 83-5 million years at Shoreham is explained by uplift and erosion which has removed all the younger Chalk and the Palaeogene deposits. Remnants of these deposits are to found in the fills to the caves. Evolution of the South Downs is illustrated by a series of cartoons (Figure 12) representing the main events from the formation of the Chalk on the sea-floor to the present day landscape (for a further explanation see fact file in www.chalkrock.com).

Once the trail and the location of the key exposures has been agreed, a simple publication identifying the main features on the trail and raising the questions about the origins of the beds and structures and the distribution of fossils could be produced as a foldout. Similar publications have been produced for many other geology trails (e.g. Wrens Nest and Lancashire Geology Trails).

6. Conclusions

6.1 Shoreham Cement Works Quarry is the last remaining accessible exposure in the South Downs of most of the Lewes Nodular Chalk Formation and its contact with the overlying Seaford Chalk Formation and the lower part of the Seaford Chalk. These two formations form the core of the South Downs and the main aquifer for potable water supply.

6.2 Nationally, the exposures in Shoreham Cement Works Quarry of the Lewes Nodular Chalk and Seaford Chalk formations, combined with the views from the quarry, perfectly illustrate the new geology of the Chalk, how it relates to the South Downs landscape and how the Chalk formations are mapped in southern Britain.

6.3. Lithological (marl seams, flint bands, hardgrounds) and fossil marker beds used for national and international correlation of the Chalk and, more broadly, the Upper Cretaceous, are well exposed in Shoreham Cement Works and some of these marker beds have their original definitions at this site.

6.4. Some fossils have been found in the Chalk at Shoreham Cement Works Quarry for the first time in the UK and other species known only in North America have been located for the first time in Europe in this section.

6.5. Shoreham Cement Works Quarry provides exceptional exposures of features related to the last approximately 2 million years of Downland landscape evolution during the Quaternary, including brown clay filled fractures, caves, collapsed cave systems and former water spouts related to sinkholes at the former land surface.

6.6. Development of a geological trail through the exposures in areas C and D of the Quarry would be of great educational value to all age groups (Figure 13). There are many fossils to be found and many ideas to be investigated relating to the origin of marl seams, some of volcanic origin, flint bands and mineralised chalk sea-beds that form hardgrounds. These would then lead on to questions about marine seafloor ecology, sea levels of the past to present and climatic cycles, perhaps a warning from the past about changes that could re-occur in the not too far distant future.

6.7. Development of a geology trail should be accompanied by a simple fold out publication illustrating the geology and setting some of the questions about origins of the sediments, the fossils, past climates and the landscape.

R.N. Mortimore   ChalkRock Ltd   07/09/2018

R. Leonard SLR

7. A list of the main publications which cite the geology of Shoreham Cement Works

Field meetings at Shoreham Cement Works

Mortimore, R.N., 1977. A reinterpretation of the Chalk of Sussex. Field Meeting for the Geologists' Association on a revision of the stratigraphy and new aspects of the sedimentology 14-15 May, 1977: Handout.

Bristow, C.R., Mortimore, R.N. and Wood, C.J., 1997. Lithostratigraphy for mapping the Chalk of southern England. Proceedings of the Geologists' Association, 108, 293-315.

This paper finalised the divisions and names of the Chalk lithostratigraphic divisions that are now mapped across southern England.

Lake, R.D., Young, B., Wood, C.J. and Mortimore, R.N. (1987) *Geology of the Country around Lewes*. Memoir of the British Geological Survey, Sheet 319 (England and Wales), HMSO, London.

The first British Geological Survey Memoir to use the new lithostratigraphical divisions of the Chalk. Members were subsequently raised to formations once it was proved they could be mapped from Dorset to the South Downs of Sussex. The final agreed divisions were published as Bristow et al. 1997.

Mortimore, R.N., 1986a. Stratigraphy of the Upper Cretaceous White Chalk of Sussex. Proceedings of the Geologists' Association, 97, 97-139.

This is the key paper that identifies Shoreham Cement Works quarry as a parastratotype for the Lewes Nodular Chalk and Seaford Chalk formations and their bed subdivisions. The sections for Shoreham Cement Works published in this paper illustrate the stratigraphical position and ranges for the most common fossils in the Chalk at this site.

Mortimore, R.N., 1986b. Controls on Upper Cretaceous sedimentation in the South Downs with particular reference to flint distribution. In: Sieveking G. de G., Hart, M.B. (Eds.), The scientific study of flint and chert, Cambridge University Press, Cambridge, pp. 21-42.

This paper identifies some of the features of the flints at Shoreham Cement works in relation to other parts of the South Downs.

Mortimore, R.N. 1990. Logging of chalk for engineering purposes. In: CHALK, Proceedings of the International Chalk Symposium 1989. Thomas Telford, London. pp. 133-152.

The collapse cave system at locality K1 is illustrated in this paper.

Mortimore, R.N. (1997) *The Chalk of Sussex and Kent.* Geologists' Association Guide No. **57**, The Geologists' Association, London.

This field guide contains most of the details of the geological exposures in Shoreham Cement Works

Mortimore, R.N., Pomerol, B., 1998. Basin analysis in engineering geology: Chalk of the Anglo-Paris basin. In: Moore, D., Hung, G., (Eds.), Proceedings of the Eighth International Congress, International Association for Engineering Geology and the Environment, Balkema, Rotterdam, pp. 3249-68.

This paper uses the example of Beeding Hardgrounds from Shoreham Cement Works to illustrate the physical properties of chalk.

Mortimore, R.N. Wood, C.J., Gallois, R.W., 2001. British Upper Cretaceous Stratigraphy. Geological Conservation Review Series, 23, Joint Nature Conservation Committee, Peterborough, p. 558.

This book is the major reference on the UK Upper Cretaceous with illustrations of many of the fossils also found at Shoreham Cement Works.

Wood, C.J., Walaszczyk, I., Mortimore, R.N., Woods, M.A., 2004. New observations on the inoceramid biostratigraphy of the higher part of the Upper Turonian and the Turonian – Coniacian boundary transition in Poland Germany and the UK. Acta Geologica Polonica, 54, 541-549.

This paper illustrates the Late Turonian and Early Coniacian fossil inoceramid bivalves also found at Shoreham Cement Works including the unique bivalve Inoceramus lusatiae ANDERT.

Woods, H. 1896. The Mollusca of the Chalk Rock Part I. Quarterly Journal of the Geological Society, February 1896, Vol. 52, 68-98, 4 plates

This paper illustrates the fossils typical of the Chalk Rock of the Chiltern Hills but never fully recorded in Sussex. All these fossils have subsequently been recorded at Shoreham Cement Works Quarry (Mortimore, 1986).

Woods, H., 1911-1912. A Monograph of the Cretaceous Lamellibranchia of England, Vol. 2, Parts 7 and 8: Inoceramus. Monograph of the Palaeontographical Society, London, pp. 262-340.

This monograph is the primary source of information on the Chalk bivalve fossils including those common at Shoreham Cement Works.

Young, B. and Lake, R.D. 1988. *Geology of the country around Brighton and Worthing*. Memoir of the British Geological Survey, Sheets 318 and 333 (England and Wales), HMSO, London.

This local British Geological Survey Memoir uses the information from Mortimore 1986 to re-illustrate the stratigraphy of the Chalk at Shoreham Cement Works.

Other references

Dixon, F. 1850. *The Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex*. Longman, Brown, Green, and Longmans, London. (new edn 1878).

Mantell, G.A. 1822. *The Fossils of the South Downs or Illustrations of the Geology of Sussex*, Lepton Relfe, London.

Mantell, G.A. 1827. *Illustrations of the Geology of Sussex,* Lepton Relfe, London.

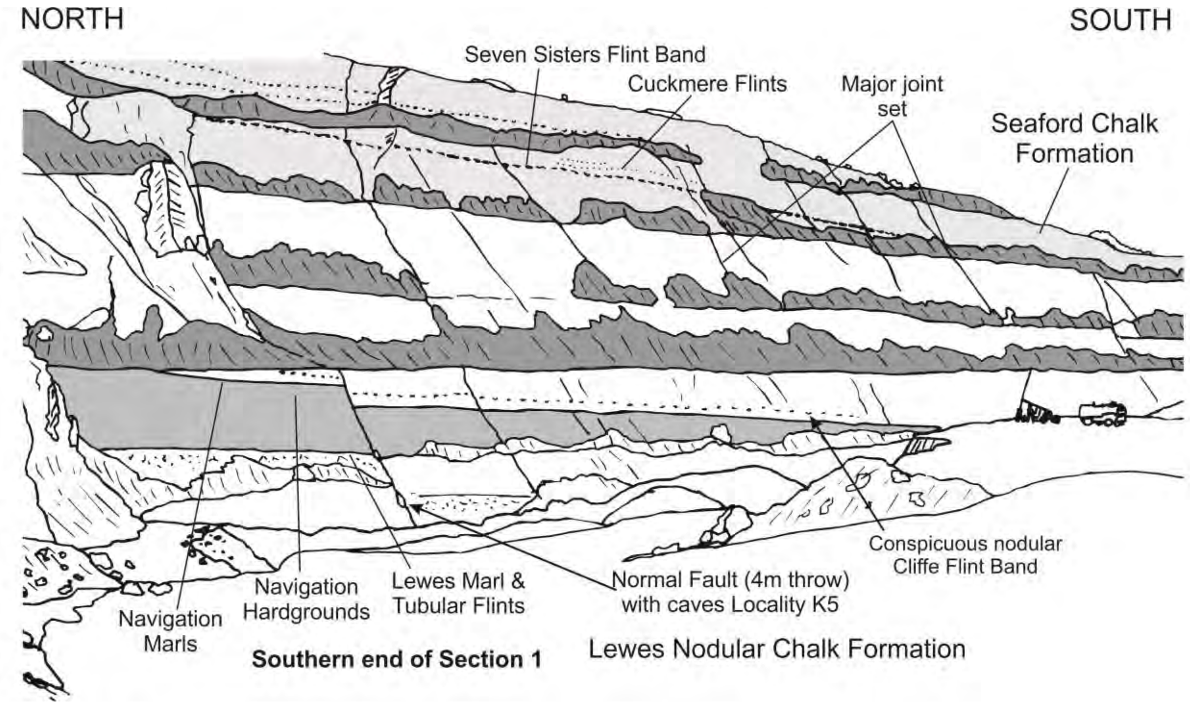


Figure 5a. Sketch of the main eastern quarry face at Shoreham Cement Works based on Mortimore 1997.

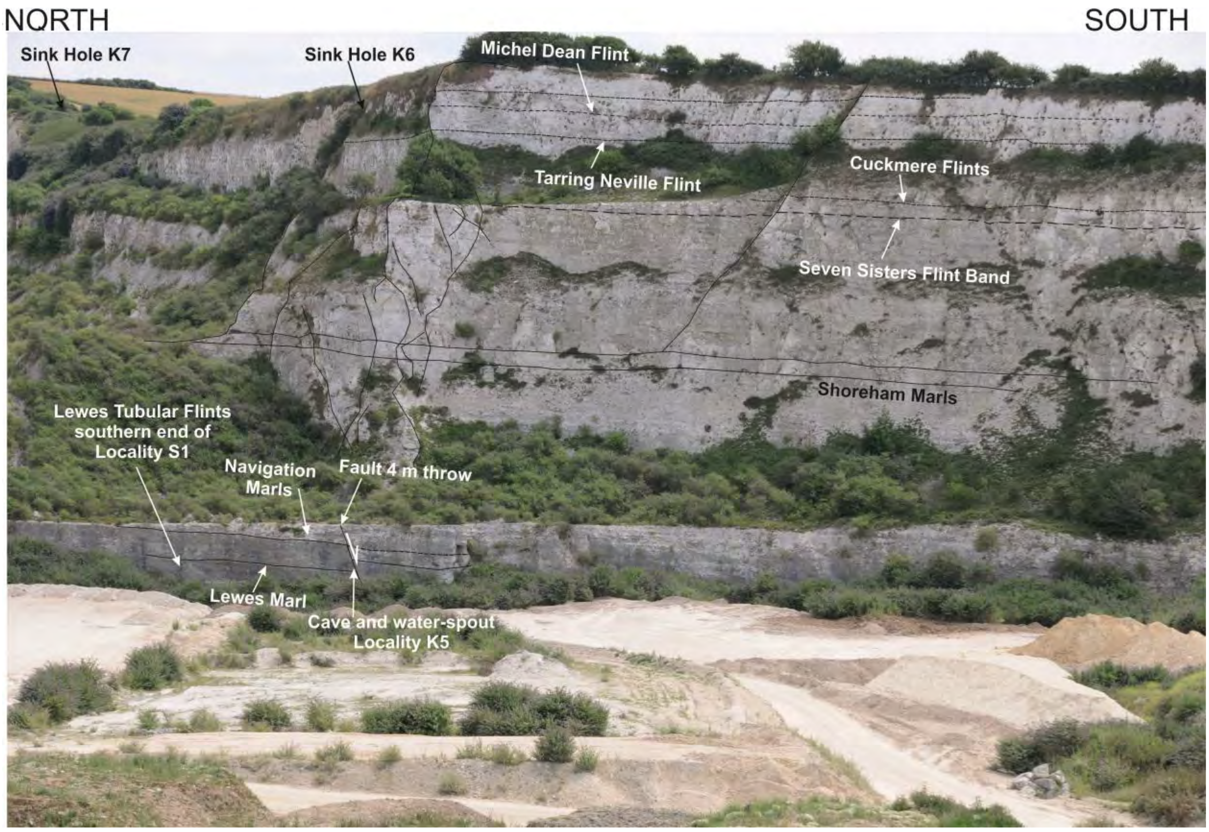


Figure 5b. The main eastern quarry face at Shoreham Cement Works as it looks now (July 2018) from viewing point V2 (Figures 3 and 13).

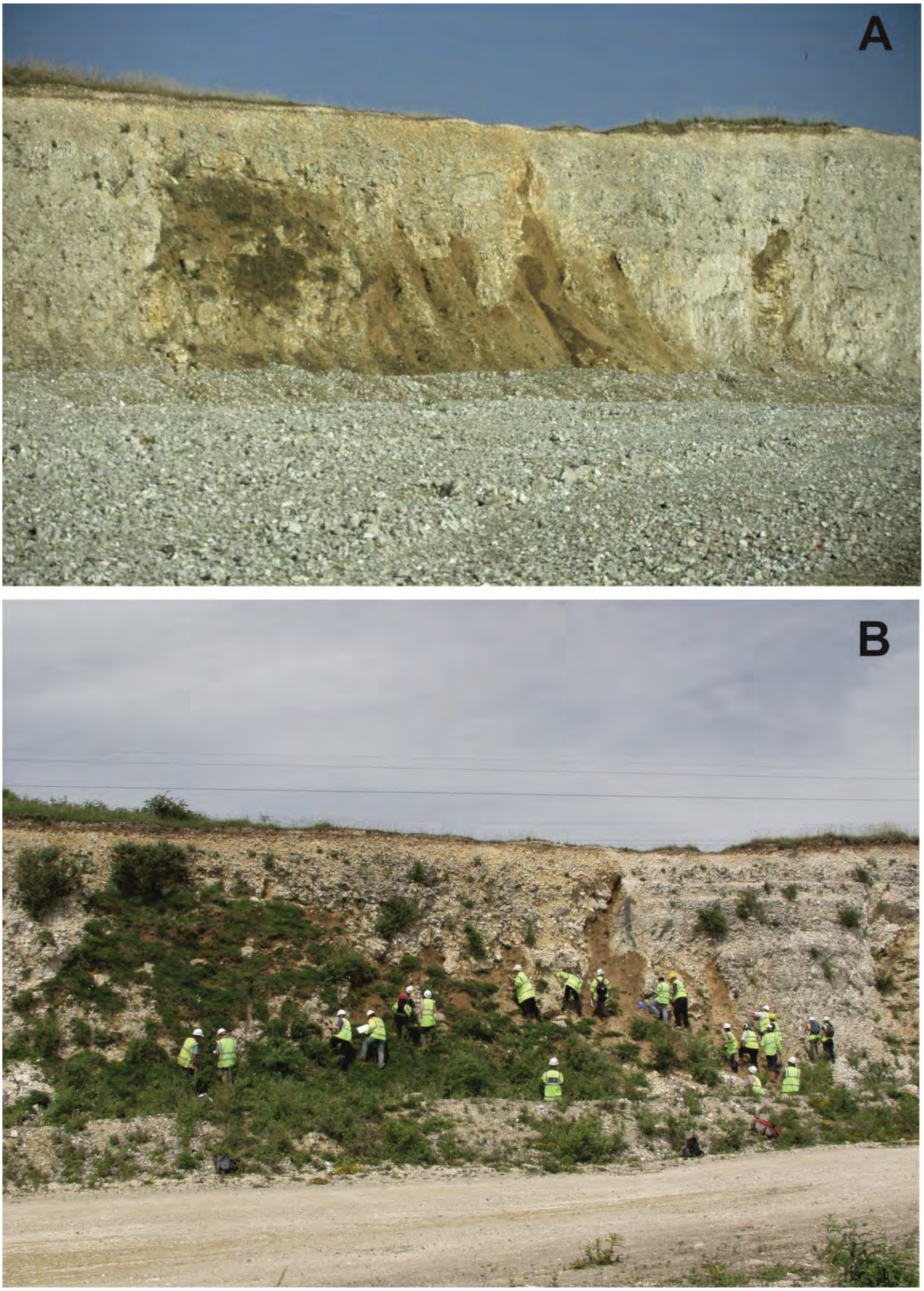


Figure 6. Locality K1 Section S5 (Figures 3 and 13) subsurface cave system in the Chalk including collapse features. A photo taken in 1978, B photo from 2002 showing students studying the features.

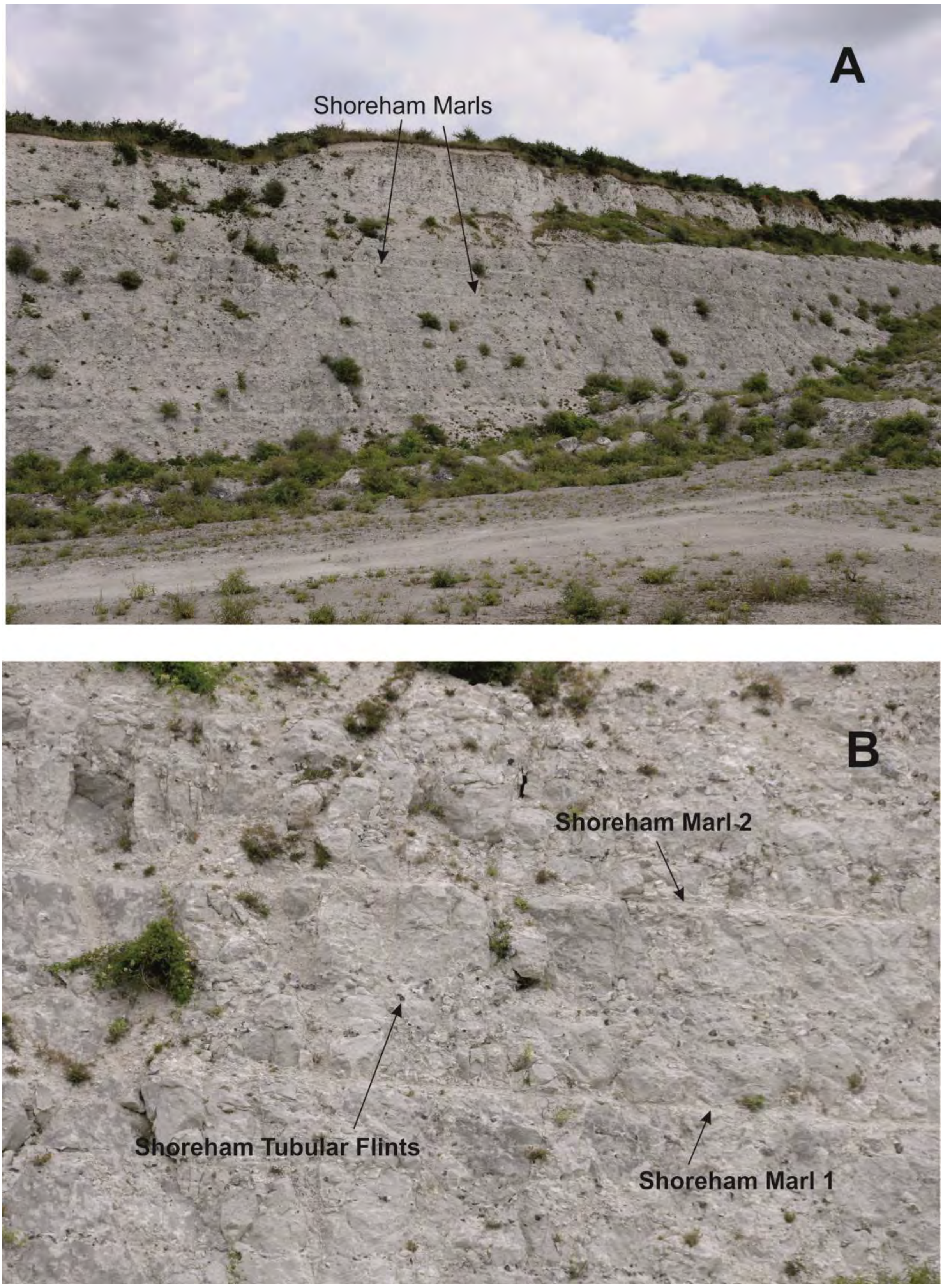
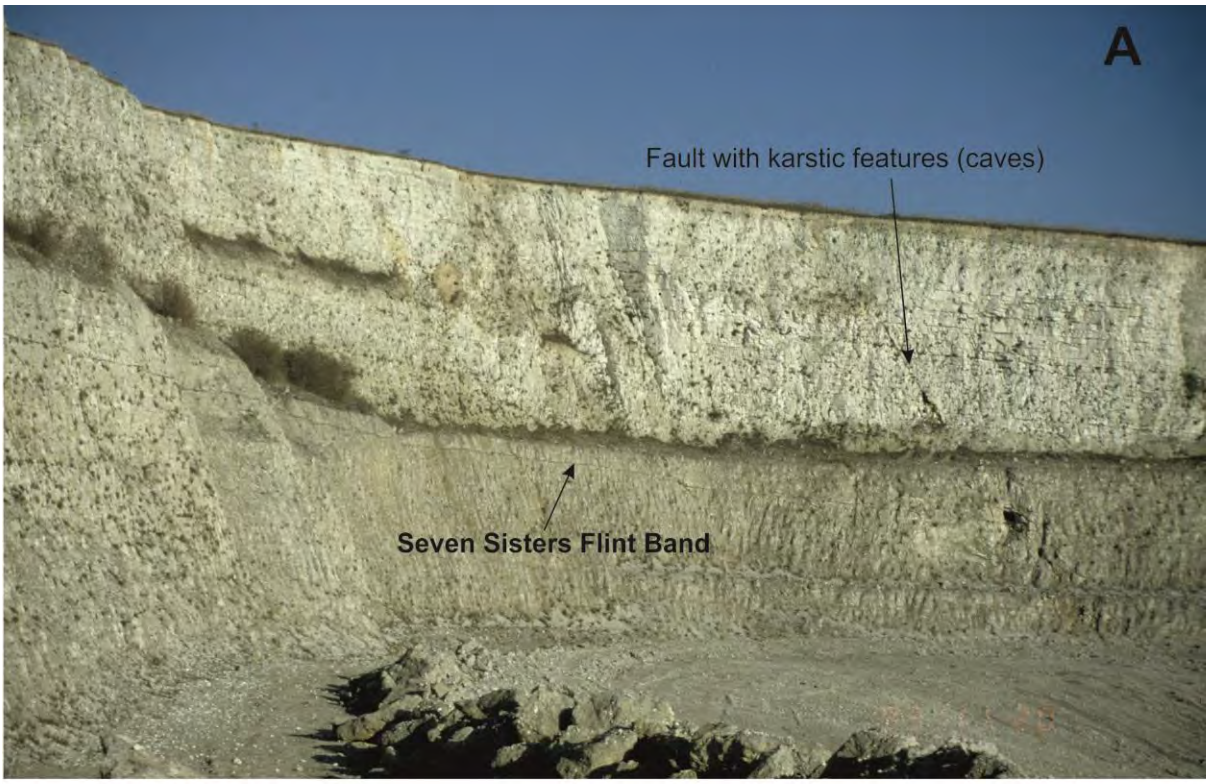


Figure 7. The type locality for the Shoreham Marls and Shoreham Tubular Flints Locality S6 (Figures 3 and 13) in Shoreham Cement Works Quarry. A an overview of the exposure, B a close up of the marl seams and the flint band.



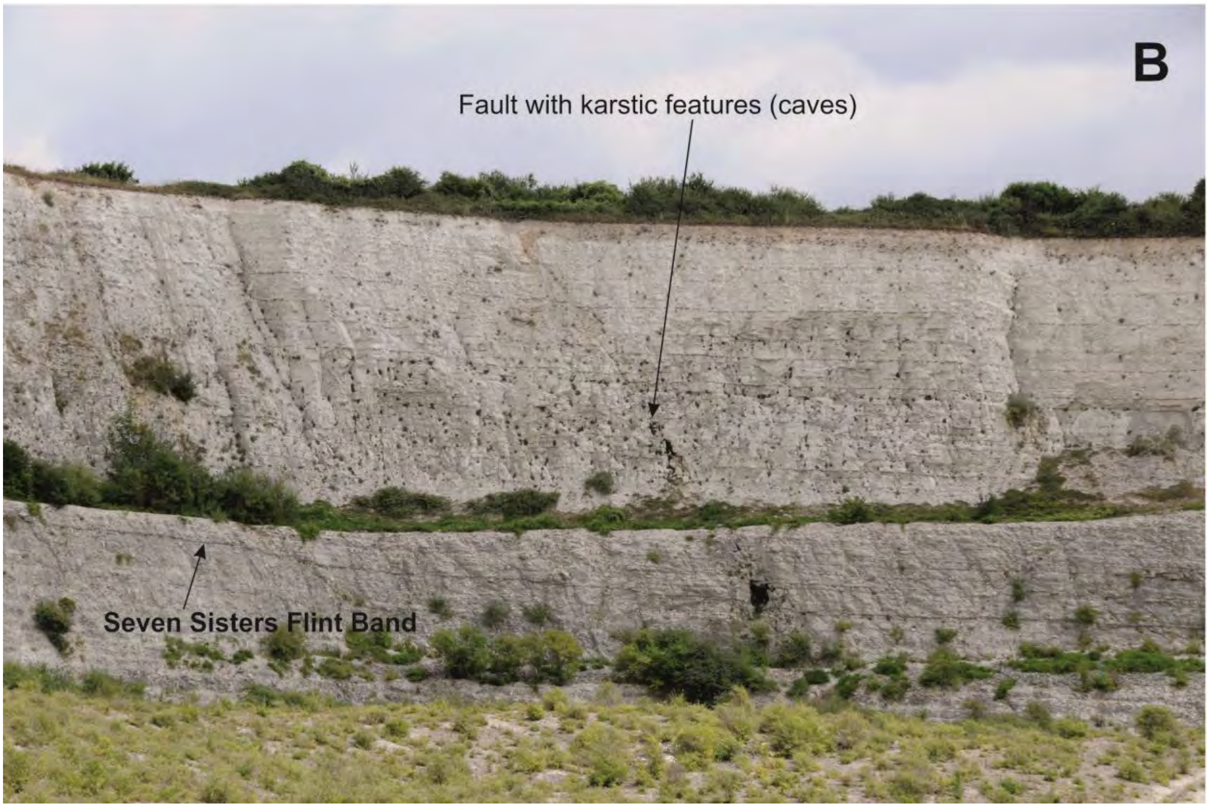


Figure 8. Topmost, youngest Chalk beds, localities S8 and S9 and K8 (Figures 3 and 13) Shoreham Cement Works Quarry Area D showing the Seven Sisters Flint Band and the Coniacian - Santonian boundary succession and the fault with karstic features K8. Photo A November 1993 and Photo B July 2018.

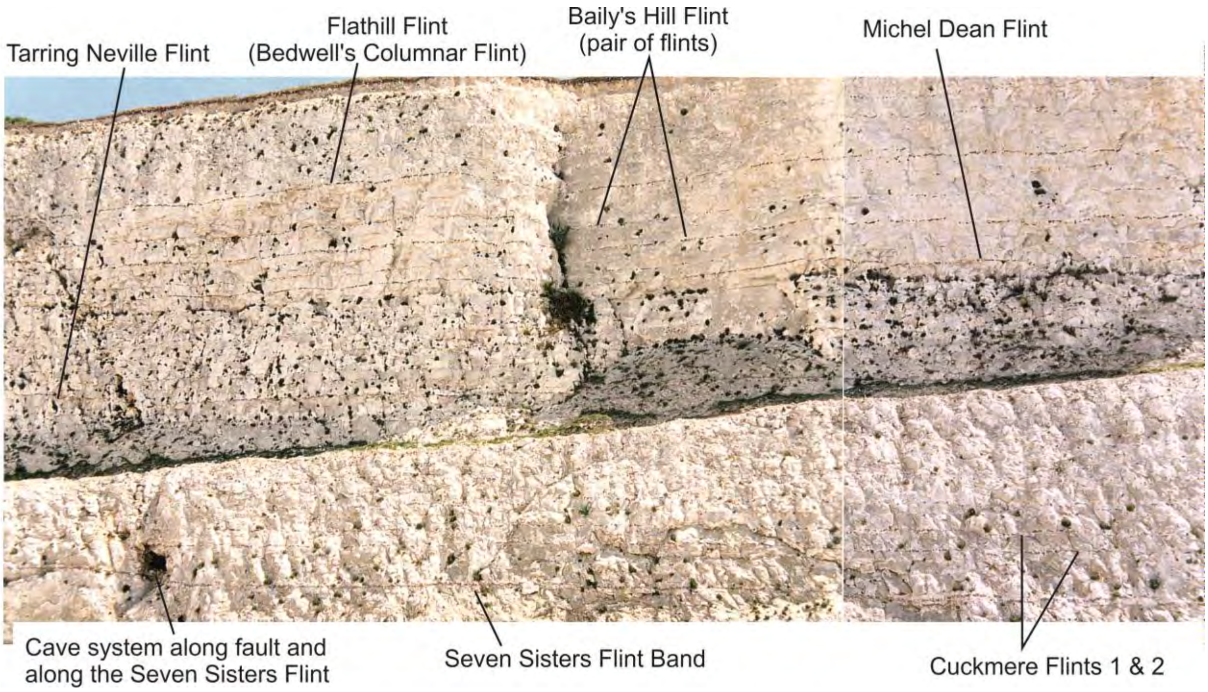


Figure 9. Topmost, youngest Chalk beds, locality Section S9 and K8 (Figures 3 and 13) Shoreham Cement Works Quarry Area D showing the Coniacian - Santonian boundary succession.

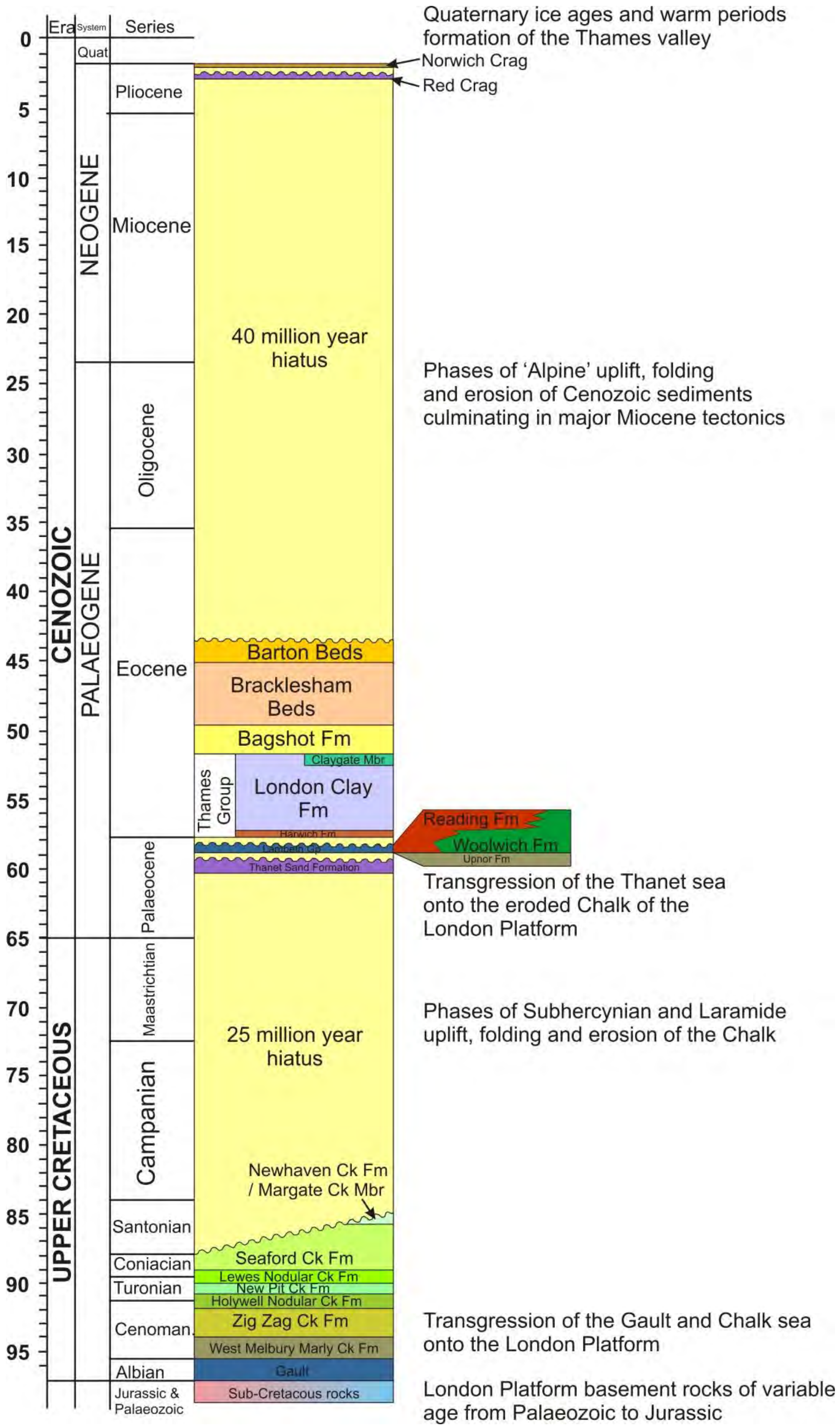


Figure 10. Schematic stratigraphical column showing that the time gaps in the geology of the London Basin region are greater than the time represented by the rocks.

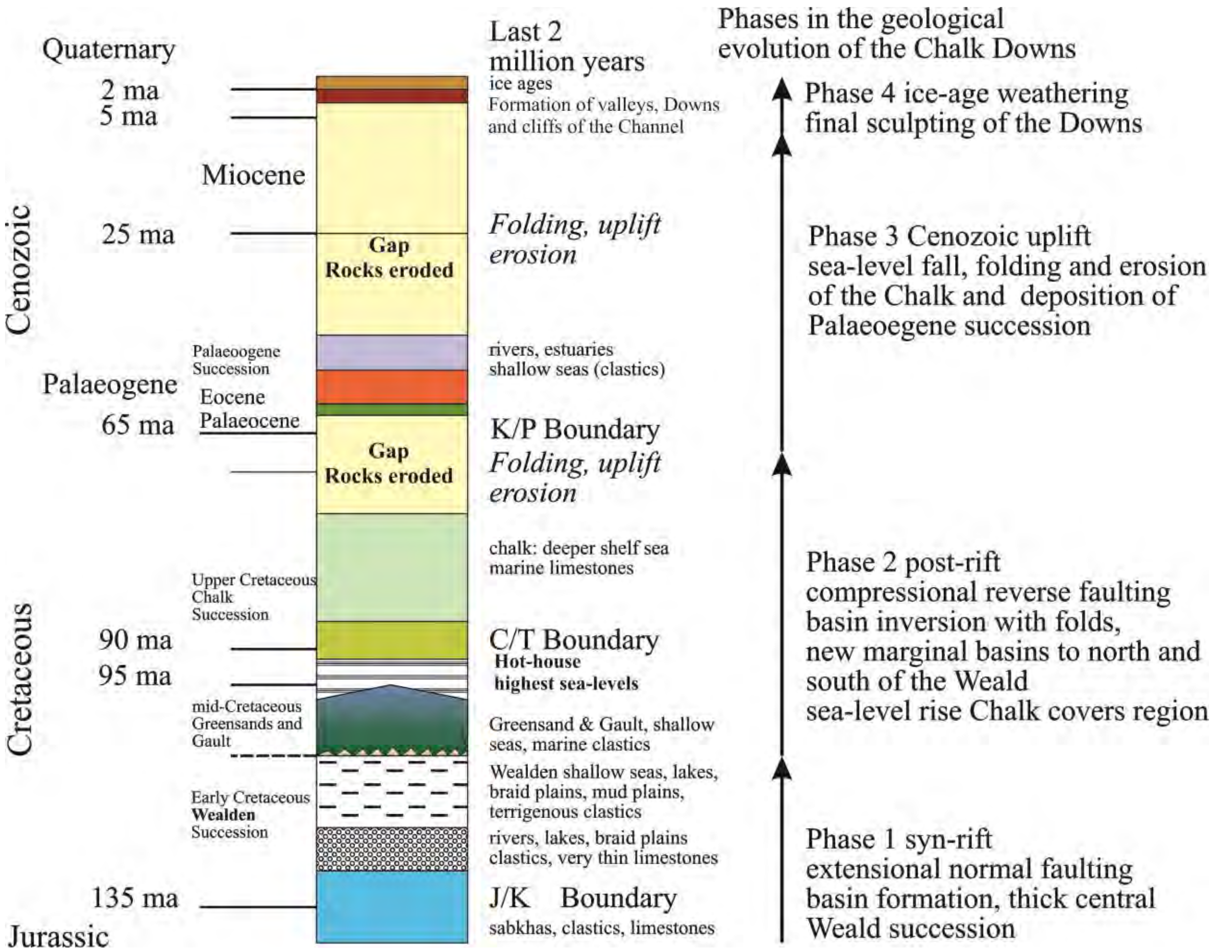


Figure 11. Schematic stratigraphical column showing that the time gaps in the geology of the Weald Basin region are greater than the time represented by the rocks for the last 100 million years..

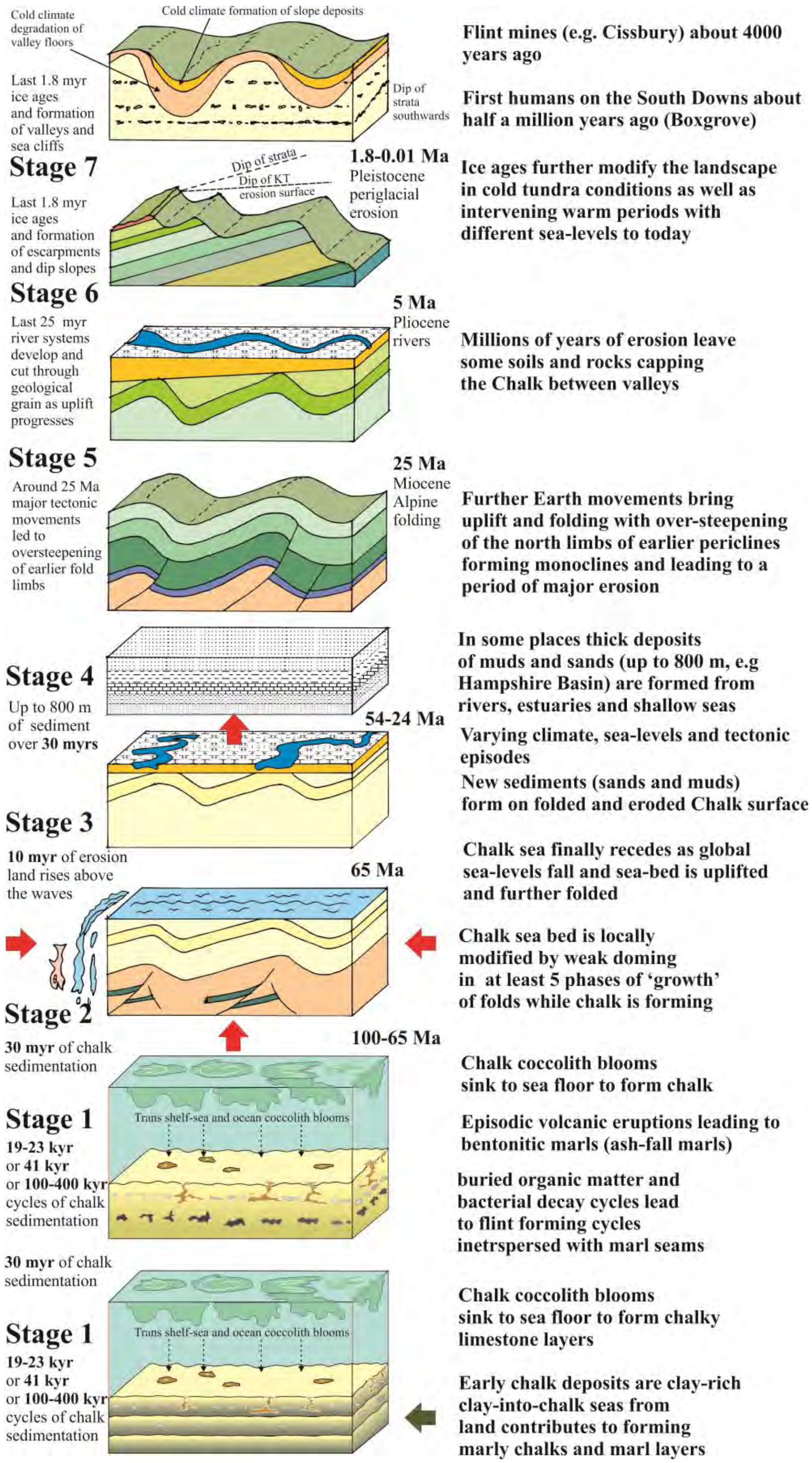


Figure 12. Schematic illustration of the stages in the evolution of the South Downs over the last 100 million years.

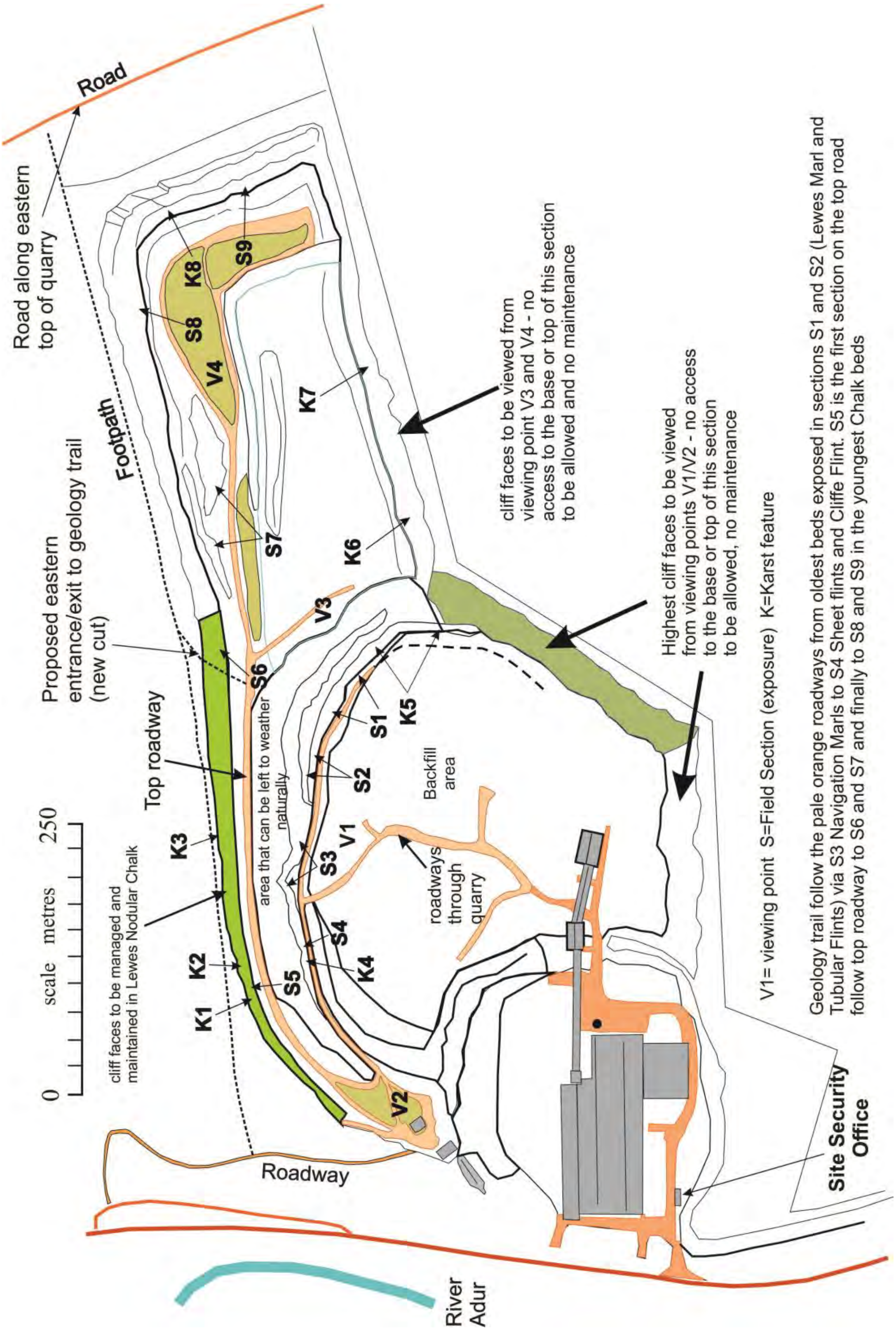


Figure 13. A proposed geology trail through Shoreham Cement Works Quarry areas C and D follows the former working quarry roadways (coloured pale orange). Note the proposed new access cut through the northern quarry face from the public footpath which joins the top access road. Localities labelled V, S and K are described in Table 1 below.

Table 1: Localities in Upper Beeding Quarry, Shoreham Cement Works, identified in the Plan Figures 3 and 13.

Locality	Details	Photograph/Figure
V1	Viewing Point V1 in the higher part of the back-filled quarry in Area C provides an overview of the main face, the lowest geological sections in the Lewes Nodular Chalk Formation and the overlying Seaford Chalk Formation (S1, S2, S3 and K4 to K5). It is suggested that the main high chalk cliff face could remain for nesting raptors etc. without the need for slope stability measures. Access to the base of the cliff face would not be allowed.	Figures 3 and 13
V2	Viewing Point V2 on the upper trackway beside the former crushing plant provides a very fine view of all the main quarry faces from where marker beds can be identified. Views west and south across the Adur River valley place the quarry exposures in context in the South Downs geology and landscape. A fenced concrete viewing platform overlooking the crushing plant remains from the former active works but would need checking for safety (and the will probably require extending).	Figures 3 and 13
V3	At the western, lower end of Area D Viewing Point V3 beside a lone small tree provides overviews of the main face and all the exposures in area D showing the position of the Shoreham Marls and the marker flint bands in the Seaford Chalk Formation. The position of the two large former sinkholes K6 and K7 on the southern wall of the Area D exposure and the trace of the karstic fault, K8, can also be studied from a distance. Additionally, views are provided of the lower benches in Area C placing them in context with the remaining Chalk geology.	Figures 3 and 13
V4	At the eastern, higher end of Area D, Viewing Point V4 provides an excellent overview of the highest (youngest) Chalk beds from the Belle Tout Marls to the Michel Dean Flint Band and very fine views back west across the quarry to the South Downs escarpments and dip slopes controlled by the various Chalk formations.	Figures 3 and 13
S1	Section 1 exposes the oldest Chalk beds which are in the Late Turonian (Figures 1 and 4) including the Bridgewick and Lewes Marl seams (volcanogenic marls), the very large Bridgewick and Bopeep flints (correlatives of the Brandon Flints in the Grimes Graves Flint Mines, Norfolk) and the unique Lewes Tubular Flints. It is only in this exposure, anywhere in southern England, that the three Bridgewick Marl seams (B1 to B3 Figures 2 and 4) are well preserved. This section also contains the rare suite of Chalk Rock Fossils (Woods, 1896) in an expanded succession compared to the Chiltern Hills, Berkshire Downs and Wiltshire Chalk. These fossils include rare ammonites as well as fossil snails, a great variety of brachiopods, bivalves and a special suite of sponge fossils. To maintain access to study this section requires clearing some of the extensive Buddleia that is now rampant across this face and on the old roadway. Sections 1 to 4 are in the part of the quarry not visible outside the pit and are, therefore, not an 'eyesore' and the 'blocky' massive chalk is relatively stable. Some minor slope stability measures could be taken (e.g. local trimming and rock bolting) which would make the faces safer and more accessible to study.	Front cover photo and Figures 3, 4 and 5a,b and 13
S2	Section S2 exposes beds above the Lewes Marl to the Navigation Hardgrounds Fig.1 (the correlative of the Top Rock of the Chiltern Hills) and the overlying Navigation Marls. Marker beds such as the	Figures 3 and 4 and Figures 3 and 13

	Cuilfail Zoophycos Beds and flint bands are well developed. Unique fossils collected from this section include the internationally important bivalve *Inoceramus lusatiae* ANDERT (Wood et al. 2004) the only well localised specimen from the English Chalk. The Navigation Hardgrounds are exceptionally hard rock beds mineralised with green glauconite, calcite and iron.	
S3	Section 3 continues the exposure of the Navigation Hardgrounds and overlying beds which contain the Turonian – Coniacian boundary fossils (see Section 4 below). The hardgrounds can be easily seen here assoicated with the fossil sea-urchins *Micraster* and *Echinocorys* and rhynchonellid brachiopods. A 3 x 3 x 3 m block from this section containing the hardgrounds and the fossils was sent to the Smithsonian Museum, Washington, to represent the Chalk of NW Europe.	Figures 3 and 13
S4	Section 4 continues the exposure of the Navigation Hardgrounds and overlying beds with the Navigation Marls which also contain the 89.8 million year Turonian – Coniacian boundary represented here by fossil bivalves including *Cremnoceramus waltersdorfensis waltersdorfensis* ANDERT in the topmost Turonian and *Cremnoceramus deformis erectus* (MEEK, 1877) in the earliest Coniacian (Wood et al. 2004). This section also exposes bedding parallel slide planes in the chalk partly replaced by sheet flints and contain unusual thin layers of fragmented flint and chalk. This is a wonderful example of processes active during formation of the Chalk rarely seen anywhere else in Europe. Sections 3 and 4 also expose many of the predominant fractures present in this quarry which are subparallel to and opening towards the Adur River valley. These fractures are filled with brown Quaternary sediments . Such features provide evidence for the geological processes active during the Quaternary evolution of the South Downs landscape (the last 2 million years).	Figures 3 and 13
S5	Section 5 at the beginning of the top road, exposes the nodular chalk layers flint bands and marl seams representing the Hope Gap, Beeding and Light Point Beds of the Lewes Nodular Chalk Formation. This is the stratotype section for the Beeding Beds containing the two Beeding Hardgrounds and the Beeding Flint Band (Mortimore 1986). A cut slice of the Beeding Hardground (N7) has been used to illustrate the range of physical properties of chalk (density, porosity, permeability) (Mortimore and Pomerol, 1998, figure 6). Section 5 also exposes the fault/fracture and bedding-controlled collapse caverns filled with brown Quaternary sediments and illustrated in Mortimore, 1990 Plate IIIc.	Figures 3 and 13
S6	Section 6 is further along the top road at the beginning of Area D, north face. This is where beds below the Shoreham Marls are exposed. The Lightpoint Marl is at the base of section and the Shoreham Marls halfway up the face. These marls are conspicuous marker beds that can be traced across the quarry faces. Fossils obtained here include the Coniacian inoceramid bivalve *Cremnoceramus crassus crassus* and the fossil sea urchin *Micraster decipiens*	Figure7 and Figures 3 and 13
S7	Section 7 includes two low banks with small chalk faces exposing the Shoreham Marls and the Shoreham Tubular Flints between them	Figures 3 and 13

	This is the finest section in this interval available in southern England and the key reference section for these beds. The Shoreham Marls are both well-developed conspicuous seams only one, however, has the chemistry indicating a volcanic ash origin. A rare fossil bivalve *Volviceramus keoneni*, has been collected from beds above the Shoreham Marls in Section 7. This is an international index fossil in the Middle Coniacian and is in the Mortimore collection.	
S8	Section S8 is in the northeast corner of Area D and provides a very fine exposure of the Belle Tout Marls and Seven Sisters Flint Band in the Belle Tout Beds of the Seaford Chalk Formation and the flint bands marking the Coniacian – Santonian boundary (at 86.3 million years). On the traverse from Section 7 to Section 8 the entry of abundant inoceramid bivalve fossils including *Platyceramus* sp and *Volviceramus* aff. *involutus* can be studied. These shells are associated with the Belle Tout Marls and are also in the Chalk to just above the Seven Sisters Flint Band (to the Cuckmere Flints, Figures 5b and 9). Many fragments are collectable from the scree slopes.	Figure 8 and Figures 3 and 13
S9	Section S9 below the eastern face of area D brings the higher beds including the Seven Sisters Flint Band, Tarring Neville Flint Band and the basal Santonian flints to lower more accessible levels. Basal Santonian fossils including the international index bivalve fossil for the base Santonian *Cladoceramus undulatoplicatus* (Roemer) is found in the cliff-fall debris on the scree-slopes. Many other fossils are also present including special forms of the sea urchin *Micraster* and rhynchonellid brachiopods.	Figures 8 and 9 Figures 3 and 13
K1	Locality K1 (Figures 3 and 13) is the first of the ancient caves with collapse chalk and Quaternary sedimentary fill along the old quarry top road (figured in Mortimore, 1990) and shown in Figure 6,A,B. Such features demonstrate the subsurface hazards present in the Chalk and illustrate the controls that fractures and bedding exert on development of such karst structures. The sedimentary fills remain to be adequately dated or studied geologically.	Figure 6 Also showing the educational value of this exposure. Figures 3 and 13
K2	Eastwards along the top road from K1 is locality K2 (Figures 3 and 13). Brown Quaternary sediments fill fractures which continue down through the Chalk to the lower roadway exposed at section 4 described above. These fractures and their fills continue downwards through the entire exposed Chalk and are also well seen in the old quarry faces on the west side of Area C.	Figures 3 and 13
K3	Locality K3 is further eastwards along the top road and exposes extensive subsurface collapse of Chalk controlled by the fracture pattern.	Figures 3 and 13
K4	Locality K4 is on the lower roadway (in Area C) and exposes several open and cavernous fractures filled with brown Quaternary sediment illustrating the continuation of the predominant set of fractures seen on the top road at localities K1 to K3.	Figures 3 and 13
K5	Locality K5 on the east wall of the old quarry in Area C (on the floor of the old Quarry). This face exposes a cave system along a prominent fault from which a water spout used to emerge during wet winters when this was a working quarry.	Figures 5a,b and Figures 3 and 13
K6	Locality K6 can be seen from Viewing Point V3 and is the smaller of two former sinkholes that were visible on old aerial photographs before Area D was excavated. This sinkhole leads down into the extensively fractured chalk at the southwest corner of Area D that continues down the eastern face of Area C.	Figures 3 and 13

K7	Locality K7 can be seen from Viewing Points V3 and V4 showing the larger of two former sinkholes that originally formed a line of sinkholes that were visible on old aerial photographs photographed before Area D was excavated. Vegetation has now largely overgrown this feature although some the sediment fill can still be seen along the margins of the feature.	Figures 3 and 13
K8	Locality K8 on the far eastern face of the quarry in Area D exposes a very fine example of a fault with caves and coarse calcite crystal-fills extensively orange, iron-stained. Part of the cave system is focussed along the Seven Sisters semi-continuous flint band where it is crossed by the fracture.	Figures 8 and 9 and Figures 3 and 13

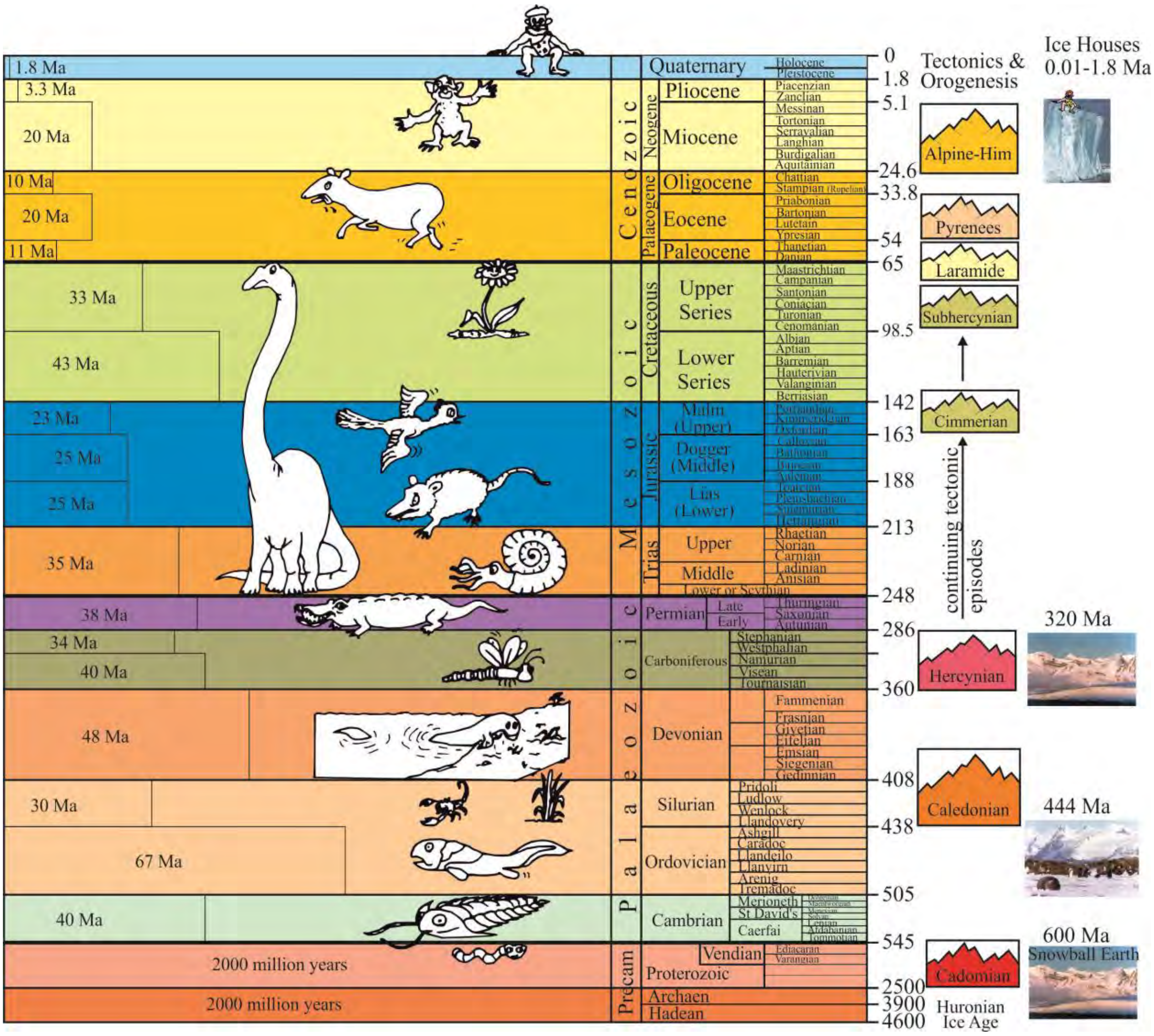


Figure 14. A geological timescale – figure added for those unfamiliar with the geologic timescale and where the Cretaceous fits into this scale. Ma =millions of years.

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