INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer all the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do not write in the bar codes.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- Where you see this icon you will be awarded a mark for the quality of written communication in your answer.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- The total number of marks for this paper is 100.
- This document consists of 20 pages. Any blank pages are indicated.
1 (a) Sedimentary rocks are classified into clastic and non-clastic rocks.

(i) Describe the term clastic.

........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
[1]

(ii) Non-clastic sedimentary rocks are divided into two types based on how they form.
State the two types of non-clastic rocks.

1 ........................................................................................................................................
2 ...........................................................................................................................................
[1]

(b) (i) Complete the classification diagram below by entering the names of the correct clastic sedimentary rocks in boxes A, B, C and D.

<table>
<thead>
<tr>
<th>Grain size</th>
<th>Composition</th>
<th>Grain shape</th>
<th>Rocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>coarse</td>
<td>rock (lithic) fragments quartz cement or matrix</td>
<td>angular</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>rounded</td>
<td>B</td>
</tr>
<tr>
<td>medium</td>
<td>&gt;90% quartz</td>
<td>well-rounded</td>
<td>orthoquartzite</td>
</tr>
<tr>
<td></td>
<td>25% K feldspar 50% quartz 25% rock (lithic) fragments</td>
<td>sub-angular to sub-rounded</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>25% clay matrix 50% rock (lithic) fragments and other minerals 25% quartz</td>
<td>sub-angular to sub-rounded</td>
<td>D</td>
</tr>
<tr>
<td>fine</td>
<td>90% mineral E 10% quartz</td>
<td>too fine to observe</td>
<td>shale</td>
</tr>
</tbody>
</table>

(ii) State the range of sizes used to define medium grains in sedimentary rocks.

........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
[1]

(iii) Identify mineral E that is found in the fine-grained clastic rocks.

........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
[1]
(iv) Use labelled diagrams to show the difference between angular and rounded grains.

| angular | rounded |

(c) (i) Describe three characteristics of desert sandstone.

1. ..............................................................
2. ..............................................................
3. ..............................................................

(ii) Describe three characteristics of sandstone formed in a fluvio-glacial environment.

1. ..............................................................
2. ..............................................................
3. ..............................................................

(d) Complete the following sentences by writing the correct terms in the spaces. Choose terms from the list below. Each term should be used only once or not at all.

bioclastic calcite coccoliths concentric

  crinoids quartz nucleus oolite

In .............................................. limestone, 75% of the rock is composed of shell fragments and the rest of the rock is a mineral cement of .............................................. .

Chalk is composed of .............................................. .

A limestone formed in shallow seas where tidal action or currents have moved particles is called .............................................. limestone. It has .............................................. layers of calcium carbonate around a .............................................. .
The diagrams below show features of three types of volcanic eruptions F, G and H.

<table>
<thead>
<tr>
<th>Volcanic eruptions</th>
<th>Simplified cross-section of volcanoes</th>
<th>Volcanic products</th>
<th>Tick (✓) if present</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>![Diagram F]</td>
<td>lava</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>tuff</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ignimbrite</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>![Diagram G]</td>
<td>lava</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>tuff</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ignimbrite</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>![Diagram H]</td>
<td>lava</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>tuff</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ignimbrite</td>
<td></td>
</tr>
</tbody>
</table>

(a) (i) Complete the table using ticks (✓) to show which volcanic product or products are formed by each volcanic eruption type.

(ii) Identify the point on the VEI scale for each volcanic eruption type F, G and H. Use the information in the table below and the diagrams of the volcanic eruption types above. Write F, G and H once only in the correct boxes in the last column of the table.

<table>
<thead>
<tr>
<th>VEI scale</th>
<th>Ejecta volume (km³)</th>
<th>Description</th>
<th>Cloud column height (km)</th>
<th>Frequency</th>
<th>Volcanic eruption type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>&lt; 0.0001</td>
<td>effusive</td>
<td>&lt; 0.1</td>
<td>constant</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>&gt; 0.0001</td>
<td>effusive</td>
<td>0.1–1</td>
<td>daily</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>&gt; 0.001</td>
<td>explosive</td>
<td>1–5</td>
<td>weekly</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>&gt; 0.01</td>
<td>explosive</td>
<td>3–15</td>
<td>few months</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>&gt; 0.1</td>
<td>explosive</td>
<td>10–25</td>
<td>≥ 1 yr</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>&gt; 1</td>
<td>explosive</td>
<td>20–35</td>
<td>≥ 10 yrs</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>&gt; 10</td>
<td>explosive</td>
<td>&gt; 30</td>
<td>≥ 100 yrs</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>&gt; 100</td>
<td>explosive</td>
<td>&gt; 40</td>
<td>≥ 1 000 yrs</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>&gt; 1000</td>
<td>explosive</td>
<td>&gt; 50</td>
<td>≥ 10 000 yrs</td>
<td></td>
</tr>
</tbody>
</table>
(b) (i) Describe how an ignimbrite forms.
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...........................................................................................................................................
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...........................................................................................................................................
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...........................................................................................................................................
........................................................................................................................................... [2]

(ii) Describe how an agglomerate forms.
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...........................................................................................................................................
........................................................................................................................................... [2]

(c) Describe the stages of caldera formation during and after final eruption. You should use labelled diagrams.

<table>
<thead>
<tr>
<th>Labelled diagrams</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>During final eruption</strong></td>
<td>.................................................................</td>
</tr>
<tr>
<td></td>
<td>.................................................................</td>
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<td></td>
<td>.................................................................</td>
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<td>.................................................................</td>
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<tr>
<td></td>
<td>.................................................................</td>
</tr>
<tr>
<td><strong>After final eruption</strong></td>
<td>.................................................................</td>
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<tr>
<td></td>
<td>.................................................................</td>
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<td>.................................................................</td>
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<tr>
<td></td>
<td>.................................................................</td>
</tr>
</tbody>
</table>

[4]

[Total: 13]
3 The graph below shows the crystal size and silica percentage for three igneous rocks.

![Graph showing crystal size and silica percentage for three igneous rocks: basalt, gabbro, and granite.](image)

(a) (i) On the graph, clearly plot and label the rocks andesite and dolerite. [2]

(ii) State the minerals found in the rocks gabbro and granite that are used to classify them.

   gabbro .................................................................................................................................. [2]

   granite .................................................................................................................................... [2]

(iii) Describe the relationship between the rock colour and mineral content of gabbro and of granite.

   gabbro ........................................................................................................................................

   ................................................................................................................................................

   granite .................................................................................................................................... [2]

(iv) Explain why silica composition is not used to identify igneous rocks in the field.

   ................................................................................................................................................

   ................................................................................................................................................ [1]
(b) Indicate whether the following statements apply to lava flows or sills or both. Use ticks (✓) in the correct column(s). The first statement has been completed for you.

<table>
<thead>
<tr>
<th>Feature seen</th>
<th>lava flow</th>
<th>sill</th>
</tr>
</thead>
<tbody>
<tr>
<td>forms a concordant feature</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>crystal size is 1 to 5 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>crystallisation has taken place more than 1 km below the surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>has two baked margins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>may have a weathered surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>the rate of cooling is measured in days or weeks</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(c) (i) Draw a fully labelled diagram to show vesicular texture in basalt. Show an appropriate scale in mm.

(ii) Describe how porphyritic texture forms in granite.

...........................................................................................................................................
...........................................................................................................................................
...........................................................................................................................................
........................................................................................................................................... [2]

[Total: 15]
4 (a) The diagrams below show cross-sections of two sedimentary structures J and K.

(i) Identify structure J and explain how it forms.

identification .................................................................................................................
formation .........................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................[2]

(ii) Identify structure K and explain how it forms.

identification ......................................................................................................................
formation .............................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................[2]

(b) In the space below, draw a labelled cross-section to show imbricate structure. Draw an arrow to show the direction of the current that formed the imbricate structure that you have drawn.

imbricate structure

[2]
(c) The cross-section diagram below shows sedimentary structures that were formed by turbidity currents on the deep sea floor.

(i) Identify these sedimentary structures.
.................................................................................................................................................. [1]

(ii) Describe how these sedimentary structures form.
..................................................................................................................................................
..................................................................................................................................................
..................................................................................................................................................
..................................................................................................................................................
.................................................................................................................................................. [2]

(iii) Name the two rocks L and M that are shown on the diagram.
rock L ........................................................................................................................................ [2]
rock M ........................................................................................................................................

(d) Explain how an alternating sequence of rocks L and M forms.
..................................................................................................................................................
..................................................................................................................................................
..................................................................................................................................................
..................................................................................................................................................
..................................................................................................................................................
.................................................................................................................................................. [3]

(e) Calcareous ooze forms on the deep sea floor. Describe how it forms.
..................................................................................................................................................
..................................................................................................................................................
..................................................................................................................................................
..................................................................................................................................................
..................................................................................................................................................
..................................................................................................................................................
.................................................................................................................................................. [2]
5 (a) State the meaning of the term polymorph.

...........................................................................................................................................................................[1]

(b) The graph below shows the stability fields of the $\text{Al}_2\text{SiO}_5$ polymorphs.

![Graph showing stability fields of $\text{Al}_2\text{SiO}_5$ polymorphs.](image)

(i) Plot the kyanite/sillimanite boundary line using the data that at 8 kb pressure the temperature will be 600 °C. [1]

(ii) State which of the minerals will be found in high-grade regional metamorphic rocks. ...........................................................................................................................................................................[1]

(iii) State the polymorph that will form at 15 km depth if the geothermal gradient is 30 °C/km. ...........................................................................................................................................................................[1]

(c) Explain how paired metamorphic belts form by regional metamorphism at a convergent plate boundary where subduction is taking place.

.......................................................................................................................................................................................................

.......................................................................................................................................................................................................

.......................................................................................................................................................................................................

.......................................................................................................................................................................................................

.......................................................................................................................................................................................................

.......................................................................................................................................................................................................

...........................................................................................................................................................................[2]
(d) The thin section diagrams below show rocks N and P produced by regional metamorphism.

(i) Identify and describe the texture of rock N and explain how this texture formed.

Rock N

![Diagram of Rock N](image)

- Texture identification: ........................................................................................................
- Texture description: ...........................................................................................................
- Texture formation: ............................................................................................................

(ii) Identify and describe the texture of rock P and explain how this texture formed.

Rock P

![Diagram of Rock P](image)

- Texture identification: ........................................................................................................
- Texture description: ...........................................................................................................
- Texture formation: ............................................................................................................

[Total: 12]
6 (a) (i) Describe the division of the geological column into eras and systems. You may use examples in your answer.

Era:........................................................................................................................................
........................................................................................................................................

System:.......................................................................................................................................
..................................................................................................................................................

(ii) State the two principles of dating that are used to construct the geological column.
1 .................................................................................................................................
2 ................................................................................................................................. [1]

(b) The table below shows historic eruption data from the Icelandic volcano Hekla.

<table>
<thead>
<tr>
<th>Date of historic eruption</th>
<th>Silica % of lava</th>
<th>Time from previous eruption (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1510</td>
<td>63</td>
<td>121</td>
</tr>
<tr>
<td>1597</td>
<td>61</td>
<td>87</td>
</tr>
<tr>
<td>1636</td>
<td>58</td>
<td>39</td>
</tr>
<tr>
<td>1693</td>
<td>58</td>
<td>57</td>
</tr>
<tr>
<td>1766</td>
<td>60</td>
<td>73</td>
</tr>
<tr>
<td>1845</td>
<td>60</td>
<td>79</td>
</tr>
<tr>
<td>1947</td>
<td>63</td>
<td>102</td>
</tr>
<tr>
<td>1970</td>
<td>55</td>
<td>23</td>
</tr>
<tr>
<td>1991</td>
<td>54</td>
<td>21</td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td>9</td>
</tr>
</tbody>
</table>

(i) Estimate a possible silica % value for the eruption in 2000.
......................................................................................................................... [1]

(ii) Calculate the average silica % of all the lavas erupted from 1510 to 1991.
......................................................................................................................... [1]

(iii) Use data from the table and your knowledge of the process of magmatic differentiation to explain why eruptions of Hekla vary in silica % over time.
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................ [2]

[Total: 7]

Turn over
Describe the main processes of the rock cycle operating at and just below the surface to a maximum depth of 500 m.

Diagrams are not required in your answer.

In your answer you must describe the effects of named processes of the rock cycle and use technical terms where appropriate.
Describe the effects of contact metamorphism produced by a granite batholith on surrounding beds of shale and limestone.

You may use diagrams to illustrate your answer.

In your answer you should describe the characteristics and distribution of the rocks around the granite batholith formed by contact metamorphism at different grades.
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