



National Certificate of Educational Achievement
TAUMATA MĀTAURANGA Ā-MOTU KUA TAEA

Exemplar for Internal Achievement Standard

Earth and Space Science Level 3

This exemplar supports assessment against:

Achievement Standard 91412

Investigating the evidence related to dating geological event(s)

An annotated exemplar is an extract of student evidence, with a commentary, to explain key aspects of the standard. It assists teachers to make assessment judgements at the grade boundaries.

New Zealand Qualifications Authority

To support internal assessment

	Grade Boundary: Low Excellence
1.	<p>For Excellence, the student needs to comprehensively investigate the evidence related to dating geological event(s).</p> <p>This involves:</p> <ul style="list-style-type: none">• justifying how a range of key evidence contributes to the understanding of the dating of the geological event(s)• explaining how the cross-correlation of the evidence contributes to the understanding of the dating of geological event(s). <p>This student has conducted a comprehensive investigation by dating the Park Volcanics group in south-east Southland. Relevant dating techniques have been investigated, justifying those selected (1). A final age has been cross-correlated using 3 techniques (2).</p> <p>For a more secure Excellence, the student could explain comprehensively how the Rb-Sr dating technique works, its half-life and decay method and why it was selected for cross-correlation. ^{87}Rb decays to ^{87}Sr with a half-life of 48.8 billion years and is accurate as long as no metamorphism occurs. This is true in the Park Volcanics.</p>

Please note – This is an extract from one student’s response

The Age of the Park Volcanics Group SE Southland.

The Event:

Shallow intrusive rocks with some extrusive rocks make up the Park Volcanic Group in SE Southland. They exist in rocks of the Triassic-Jurassic age. They include andesites, dacites and some ignimbrite. The rocks are primarily andesites and suggest emplacement in a back arc setting near an island arc system to the east. The prominent hill near Pomahaka suggests a sill, a shallow intrusive event, but the top of the layer is never exposed. These rocks make up the only volcanic rocks exposed in the Southland Syncline which formed off the east coast of Australia when New Zealand was still part of Australia. These volcanic rocks have been dated as they give the youngest age of the Southland syncline.

Dating techniques for older rocks:

Dating of older rocks (about 200ma) requires techniques with a half-life of greater than 1 million years. This is to get the accuracy required. Young dating techniques like ^{14}C are no use as the half-life of ^{14}C is only 5300 years and would all be gone before 100 000 years is up. Key methods are described below. ①

Potassium-Argon Dating

K-Ar dating is based on measurement of the product of the radioactive decay of an isotope of potassium (K), which is a common element found in many materials, such as micas, clay minerals, tephra, and evaporites, into argon. The decay product ^{40}Ar starts to accumulate when the rock solidifies (re-crystallises). Time since re-crystallization is calculated by measuring the ratio of the amount of ^{40}Ar accumulated to the amount of ^{40}K remaining. The long half-life of ^{40}K allows the method to be used to calculate the absolute age of samples. This is an accurate measure but the sample must be divided into two and each analysed separately. ①

Argon-Argon Dating

Argon-argon (or $^{40}\text{Ar}/^{39}\text{Ar}$) dating is a radiometric dating method invented to supersede potassium-argon (K-Ar) dating in accuracy. This technique differs from the K-Ar technique in that prior to measurement in a mass spectrometer, the sample is irradiated with neutrons in a nuclear reactor and some of the ^{39}K (present as a known fraction of the total K in the rock) is converted to ^{39}Ar . The ratio of the radiogenic daughter product, $^{40}\text{Ar}^*$, to ^{39}Ar (as a proxy for ^{40}K) can be measured in the same sample. $^{40}\text{Ar}^*$ has a short half-life (269 years) so any

present in the rock would be negligible and hence all $^{40}\text{Ar}^*$ is produced from ^{40}K . The half-life of ^{40}K is 1.248×10^9 ①

Rubidium-Strontium Dating

The rubidium-strontium dating method is a radiometric dating technique to determine the age of rocks. The utility of the rubidium-strontium isotope system results from the fact that ^{87}Rb decays to ^{87}Sr . This method is useful for igneous rocks ①

Uranium-Lead Dating

Uranium-lead is one of the oldest and most refined radiometric dating schemes, with a routine age range of about 1 million years to over 4.5 billion years, and with routine precisions in the 0.1-1 percent range. The method relies on two separate decay routes, from ^{238}U to ^{206}Pb and ^{235}U to ^{207}Pb . These decay routes occur via a series of alpha (and beta) decays. ①

Cross correlation of the techniques to give the final age of the Park Volcanics.

The Park Volcanic rocks have been dated using three techniques used above. They have been dated as set out below.

Technique	Age (ma)	Error
^{40}K - ^{40}Ar	206	+/- 2.5ma
$^{40}\text{Ar}^*$ - ^{39}Ar	199.6	+/- 0.8ma
^{87}Rb - ^{87}Sr	197.5	+/- 2.2ma

These three dating techniques give ages that agree within the percentage error so improve the accuracy of the final age overall. These ages are at the boundary of the Triassic / Jurassic geological ages. ^{87}Rb - ^{87}Sr and $^{40}\text{Ar}^*$ - ^{39}Ar give an age at the boundary while K-Ar gives a young Jurassic age. Overall, and because of the accuracy of the $^{40}\text{Ar}^*$ - ^{39}Ar method, I would date the age of the Park Volcanics as 199.6ma +/- 1ma. The small error range for the $^{40}\text{Ar}^*$ - ^{39}Ar helps confirm the accuracy of the 199.6 age.

This places the rock age right at the Triassic-Jurassic boundary. ②

	Grade Boundary: High Merit
2.	<p>For Merit, the student needs to investigate in depth the evidence related to dating geological event(s).</p> <p>This involves explaining, in detail, how a range of key evidence contributes to the understanding of the dating of geological event(s).</p> <p>This student has conducted an in-depth investigation by dating the Park Volcanics group in south-east Southland. Dating techniques have been investigated in depth, and the key techniques have been selected and justified (1)</p> <p>To reach Excellence, the student could explain in depth a cross-correlation using the ^{40}Ar-^{39}Ar and ^{40}K-^{40}Ar methods to narrow down the final agreed age of 199.6ma. The student could also explain how these two methods are most accurate because Argon accumulates after the final crystallisation of igneous rocks. The significance of the small error range for ^{40}Ar*-^{39}Ar could be discussed.</p>

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Dating techniques for older rocks:

Dating of older rocks (about 200ma) requires techniques with a half-life of greater than 1 million years. This is to get the accuracy required. ① Young dating techniques like ^{14}C are no use as the half-life of ^{14}C is only 5300 years and would all be gone before 100 000 years is up. Key methods are described below.

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present in the rock would be negligible and hence all $^{40}\text{Ar}^*$ is produced from ^{40}K . The half-life of ^{40}K is 1.248×10^9 ①

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^{87}Rb - ^{87}Sr	197.5	+/- 2.2ma

These three dates state that the rocks are 199.6ma.

	Grade Boundary: Low Merit
3.	<p>For Merit, the student needs to investigate in depth the evidence related to dating geological event(s).</p> <p>This involves explaining, in detail, how a range of key evidence contributes to the understanding of the dating of geological event(s).</p> <p>This student has conducted an in-depth investigation by dating the Park Volcanics group in south-east Southland. One dating technique has been investigated in depth and two others explained (1).</p> <p>For a more secure Merit, the student could explain in depth how the Rb-Sr and ^{40}K-^{40}Ar methods operate to give a more accurate age of the Park Volcanics, and explain that ^{40}Ar-^{39}Ar has been used as a reliable technique but geological dating requires cross-correlation with other techniques to get a more accurate age.</p>

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Potassium-Argon Dating

K-Ar dating is based on measurement of the product of the radioactive decay of an isotope of potassium (K), which is a common element found in many materials, such as micas, clay minerals, tephra, and evaporites, into argon. The decay product ^{40}Ar starts to accumulate when the rock solidifies (recrystallises). ①

Argon-Argon Dating

Argon-argon (or $^{40}\text{Ar}/^{39}\text{Ar}$) dating is a radiometric dating method invented to supersede potassium-argon (K-Ar) dating in accuracy. This technique differs from the K-Ar technique in that prior to measurement in a mass spectrometer, the sample is irradiated with neutrons in a nuclear reactor and some of the ^{39}K (present as a known fraction of the total K in the rock) is converted to ^{39}Ar . The ratio of the radiogenic daughter product, $^{40}\text{Ar}^*$, to ^{39}Ar (as a proxy for ^{40}K) can be measured in the same sample. $^{40}\text{Ar}^*$ has a short half-life (269 years) so any present in the rock would be negligible and hence all $^{40}\text{Ar}^*$ is produced from ^{40}K . The half-life of ^{40}K is 1.248×10^9 ①

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The rubidium-strontium dating method is a radiometric dating technique to determine the age of rocks. The utility of the rubidium-strontium isotope system results from the fact that ^{87}Rb decays to ^{87}Sr . ①

The final age of the Park Volcanics.

The Park Volcanic rocks have been dated using three techniques used above. These three dates state that the rocks are about 199.6ma.

	Grade Boundary: High Achieved
4.	<p>For Achieved, the student needs to investigate the evidence related to dating geological event(s).</p> <p>This involves:</p> <ul style="list-style-type: none">• explaining geological events• explaining a range of evidence related to dating geological event(s). <p>This student has conducted an investigation for dating the Park Volcanics group in south-east Southland. The event has been explained and linked to a back arc system (1). One dating technique has been investigated and two others mentioned (2).</p> <p>To reach Merit, the student could explain how the ^{40}K-^{40}Ar and Rb-Sr methods give a relevant final age of 199.6ma, and explain that dating of rocks requires a number of techniques to be used to give a more accurate result of the final age.</p>

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Dating techniques for older rocks:

Dating of older rocks (about 200ma) requires techniques with a half-life of greater than 1 million years. This is to get the accuracy required.

Argon-Argon Dating

Argon-argon (or $^{40}\text{Ar}/^{39}\text{Ar}$) dating is a radiometric dating method invented to supersede potassium-argon (K-Ar) dating in accuracy. This technique differs from the K-Ar technique in that prior to measurement in a mass spectrometer, the sample is irradiated with neutrons in a nuclear reactor and some of the ^{39}K (present as a known fraction of the total K in the rock) is converted to ^{39}Ar . The half-life of ^{40}K is 1.248×10^9 ②

Potassium-Argon Dating

K-Ar dating is based on measurement of the product of the radioactive decay of an isotope of potassium (K) into argon (Ar). The argon collects in crystals and the more Argon present the older the age. The Ratio of ^{40}K to ^{40}Ar changes with time. This gives an old age for the Park Volcanics. ②

Rubidium-Strontium Dating

The rubidium-strontium dating method is a radiometric dating technique to determine the age of rocks. ^{87}Rb decays to ^{87}Sr . ②

The final age of the Park Volcanics.

The Park Volcanic rocks have been dated using the three techniques from above and is about 200ma old.

	Grade Boundary: Low Achieved
5.	<p>For Achieved, the student needs to investigate the evidence related to dating geological event(s).</p> <p>This involves:</p> <ul style="list-style-type: none">• explaining geological events• explaining a range of evidence related to dating geological event(s). <p>This student has conducted an investigation for dating the Park Volcanics group in south-east Southland. The event has been explained and linked to the volcanic rocks erupted (1). One dating technique has been explained and one other relevant technique mentioned (2).</p> <p>For a more secure Achieved the student could explain how the ^{40}K-^{40}Ar and Rb-Sr methods give a relevant final age of 199.6ma.</p>

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Dating techniques for older rocks:

Dating of older rocks (about 200ma) requires techniques with a half-life of greater than 1 million years. This is to get the accuracy required.

Argon-Argon Dating

Argon-argon (or $^{40}\text{Ar}/^{39}\text{Ar}$) dating is a radiometric dating method invented to supersede potassium-argon (K-Ar) dating in accuracy. This technique differs from the K-Ar technique in that prior to measurement in a mass spectrometer, the sample is irradiated with neutrons in a nuclear reactor and some of the ^{39}K (present as a known fraction of the total K in the rock) is converted to ^{39}Ar . The half-life of ^{40}K is 1.248×10^9 ②

Other dating techniques:

Three other useful techniques are ^{14}C , Rb-Sr and ^{40}K - ^{40}Ar . These techniques use isotopes to give the old ages of rocks. These measure radioactive decay and from that an age can be determined. Carbon 14 is no good because it is only used for young ages. ^{40}K - ^{40}Ar is used to date the old rocks of this area. Potassium is converted to Argon and the Argon gas is trapped in crystals. ②

The age of the Park Volcanics.

The Park Volcanic rocks have been dated using two techniques from above and are 200ma old.

	Grade Boundary: High Not Achieved
6.	<p>For Achieved, the student needs to investigate the evidence related to dating geological event(s).</p> <p>This involves:</p> <ul style="list-style-type: none">• explaining geological events• explaining a range of evidence related to dating geological event(s). <p>This student has conducted an investigation for dating the Park Volcanics group in south-east Southland. The event has been explained and rocks identified (1). Two dating techniques have been explained as well as how ^{14}C is used for dating (2).</p> <p>To reach Achieved, the student could explain two relevant dating techniques and explain how relevant techniques must involve isotopes with long half-lives (greater than 1 million years) to give an age of 200ma.</p>

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Dating techniques for older rocks:

Dating of older rocks requires isotopes that undergo radioactive decay. This is constant and can be measured in the labs. Two key techniques are set out below. Argon-Argon dating and Carbon dating.

Argon-Argon Dating

Argon-argon (or $^{40}\text{Ar}/^{39}\text{Ar}$) dating is a radiometric dating method invented to supersede potassium-argon (K-Ar) dating in accuracy. This technique differs from the K-Ar technique in that prior to measurement in a mass spectrometer, the sample is irradiated with neutrons in a nuclear reactor and some of the ^{39}K (present as a known fraction of the total K in the rock) is converted to ^{39}Ar . The half-life of ^{40}K is 1.248×10^9 ②

Carbon Dating

^{14}C is accumulated during an organisms lifetime. On death the ^{14}C decays to ^{14}N by emitting a beta particle. The half-life of ^{14}C is 5000 years. This can be used to date extremely old things and events. ②

The age of the Park Volcanics.

The Park Volcanic rocks have been dated using the two techniques above and are 200ma old.