International Geoscience Syllabus, to be encountered by all pupils by the age of 16

Prepared as an internal report on behalf of the International Geoscience Education Organisation (IGEO) and the International Union of Geological Sciences Commission on Geoscience Education (IUGS-COGE) by:

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This syllabus has been prepared by the International Geoscience Education Organisation (IGEO) and the International Union of Geological Sciences Commission on Geoscience Education (IUGS-COGE)

The syllabus is based on the following principles:

- it is based on existing curricula around the world since a syllabus based on existing curricula is most likely to be globally accepted – the matrix of coverage by existing syllabuses begins on page 7;
- the structure of the international syllabus is clearly apparent, even though such structure is not readily apparent in many existing curricula;
- the syllabus is concisely presented on just one page, since a concise syllabus is more likely to be acceptable to non-Earth science educators and teachers; more detail is provided through exemplification on the following pages to indicate the extent of coverage, although it is anticipated that detail will vary from country to country
- the syllabus does not aim to indicate progression.

Contents

International Geoscience Syllabus, to be encountered by all pupils by the age of 16 – core syllabus

By the age of 16, pupils should develop an understanding of the following:

Earth as a changing system

- Attributes — open to energy, almost closed to matter, changing over time, within the solar system, comprising geosphere, hydrosphere, atmosphere, biosphere
- Interactions — interaction of geosphere, hydrosphere, atmosphere, biosphere
- Feedback — positive and negative
- Processes and products — water cycle, rock cycle, carbon cycle
- Energy sources — solar, internal

Earth is a system within the solar system, within the universe

- Origins — big bang; accretion from dust; stars; planets
- The Sun — only external energy source; fluctuations
- Rotational effects — day/night, seasons, moon phases, eclipses

Earth is a system which has changed over time

- Geological time — span, major events, relative and absolute dating methods, rates of processes

Earth's system comprises interacting spheres -

- **geosphere**
- Earth materials and properties — minerals, fossils, sedimentary, igneous and metamorphic rocks, soil
- Earth processes and preserved characteristics — surface processes, sedimentary, igneous and metamorphic processes, deformation (AW)
- Structure of the Earth and evidence — crust, mantle, core, lithosphere
- Plate tectonics and evidence — unifying theory, plate construction and subduction, characteristics of plate margins, mechanism, rates of movement; evidence

- **hydrosphere**
- Continental water — location, processes of movement, uses
- Oceanic water — composition, processes of movement

- **atmosphere**
- Composition — evolution, current composition
- Flow — processes of movement
- Change — greenhouse effect, planetary influences, human influence, impact on sea level

- **biosphere**
- Evolution — natural selection, fossil evidence, mass-extinction
- Impact on other systems — role of biosphere in Earth systems

Earth's system produces resources

- Raw materials and fossil fuels — naturally concentrated, non-renewable, uses, need careful managing (sustainable development), potentially polluting
- Renewable energy — issues

Human/Earth system interactions

- Natural hazards — human impact, forecasting, mitigation
- Environmental issues — local to global, mitigation
- Impact on human history — resource wars; migration due to climate change

Earth's system is explored through fieldwork and practical work

- Observation — observation, measurement and recording
- Synthesis of observations — interpretation
- Investigation and hypothesis-testing — devising and implementing plans, processing data, drawing conclusions, evaluating results and communicating findings

International Geoscience Syllabus, to be encountered by all pupils by the age of 16 – core syllabus *with exemplification*

By the age of 16, pupils should develop an understanding of the following:		***Exemplification of the core to indicate the extent of coverage (it is anticipated that this will vary from country to country)***
Earth as a changing system		
• Attributes	open to energy, almost closed to matter, changing over time, within the solar system, comprising geosphere, hydrosphere, atmosphere, biosphere	
• Interactions	interaction of geosphere, hydrosphere, atmosphere, biosphere	*lithosphere/hydrosphere interaction causes coastal processes; hydrosphere/atmosphere interaction causes waves and atmospheric warming; atmosphere/biosphere interaction climatically controls vegetation; lithosphere/biosphere interaction affects soil quality; rates vary from fast to slow*
• Feedback	positive and negative	*positive – increasing area of polar ice sheets gives increased reflection of solar energy, gives increased cooling, gives increasing area of polar ice sheets; negative – the more carbon dioxide is released into the atmosphere, the more that is absorbed in the oceans*
• Processes and products	water cycle, rock cycle, carbon cycle	*unique properties of water, evaporation, transpiration, condensation, precipitation; weathering/erosion, sedimentation, metamorphism, melting, igneous activity; photosynthesis, respiration, burial as limestone/fossil fuel, release by burning/weathering*
• Energy sources	solar, internal	*internal energy from radioactivity and energy from Earth's formation*
Earth is a system within the solar system, within the universe		
• Origins	big bang; accretion from dust; stars; planets	
• The Sun	only external energy source; fluctuations	*solar energy driving the water cycle and weather; long term fluctuations of energy from the Sun related to climate change*
• Rotational effects	day/night, seasons, moon phases, eclipses	
Earth is a system which has changed over time		
• Geological time	span, major events, relative and absolute dating methods, rates of processes	*major events: 4600 million years (Ma) – formation of Earth; 3600Ma – early life; 550Ma – animals with hard parts; 250Ma – major extinction, including trilobites; 65Ma – major extinction, including dinosaurs; 1Ma ice age; dating principles: superposition, cross-cutting relationships, fossil correlation; radiometric dating; processes occur on a frequency-magnitude spectrum from continuous to catastrophic*

Earth's system comprises interacting spheres -

- **geosphere**		
• Earth materials and properties	minerals, fossils, sedimentary, igneous and metamorphic rocks, soil	*definitions of: mineral, fossil, rock sedimentary rock, igneous rock, metamorphic rock, soil; minerals including: quartz, feldspar, mica, garnet, calcite, halite, gypsum, pyrite, galena; fossils including: trilobite, ammonite, dinosaur; fossilisation processes including: burial, replacement, moulds and casts, trace fossils; rock texture, porosity, permeability; sedimentary rocks including: limestone, chalk, conglomerate, sandstone, clay, shale, rock salt; sedimentary features including: layering (bedding), cross bedding, ripple marks; igneous rocks including: granite, basalt, andesite, gabbro, volcanic ash; metamorphic rocks including: slate, schist, gneiss, marble, metaquartzite (quartzite)*
• Earth processes and preserved characteristics	surface processes, sedimentary, igneous and metamorphic processes, deformation (AW)	*weathering (physical/chemical), erosion, transportation, deposition, lithification, metamorphism, intrusion, extrusion, folding, faulting, jointing*
• Structure of the Earth and evidence	crust, mantle, core, lithosphere	*seismic evidence*
• Plate tectonics and evidence	unifying theory, plate construction and subduction, characteristics of plate margins, mechanism, rates of movement; evidence	*constructive, destructive and conservative margins; past and present evidence*
- **hydrosphere**		
• Continental water	location, processes of movement, uses	*surface water, groundwater, ice caps/glaciers; infiltration, downhill flow; water resource management*
• Oceanic water	composition, processes of movement	*salinity; surface flow and waves caused by wind; deep flow due to density differences caused by temperature and salinity*
- **atmosphere**		
• Composition	evolution, current composition	*outgassing by early volcanic activity; nitrogen, oxygen, trace gasses including water vapour and carbon dioxide*
• Flow	processes of movement	*unequal heating of Earth, flow due to density differences caused by temperature, oceanic heat source*
• Change	greenhouse effect, planetary influences, human influence, impact on sea level	*temperature graphs over different time spans; link between temperature change and sea level*

- **biosphere**		
• Evolution	natural selection, fossil evidence, mass-extinction	*palaeogeographical effects on evolution; mass-extinction by volcanic activity and impact*
• Impact on other systems	role of biosphere in Earth systems	*biological weathering; biological deposition*
Earth's system produces resources		
• Raw materials and fossil fuels	naturally concentrated, non-renewable, uses, need careful managing (sustainable development), potentially polluting	*oil/gas; metal ores; bulk raw materials; local examples of mining/quarrying*
• Renewable energy	issues	*low pollution, cost, regularity of supply*
Human/Earth's system interactions		
• Natural hazards	human impact, forecasting, mitigation	*eruption; earthquake; tsunami; landslide*
• Environmental issues	local to global, mitigation	*global human impact (causing erosion, pollution, drainage-changes mining/quarrying); burning fossil fuels and greenhouse effect*
• Impact on human history	resource wars; migration due to climate change	
Earth's system is explored through fieldwork and practical work		
• Observation	observation, measurement and recording	
• Synthesis of observations	interpretation	*environment of rock-formation; geological history; environmental issues*
• Investigation and hypothesis-testing	devising and implementing plans, processing data, drawing conclusions, evaluating results and communicating findings	

Matrix of coverage by current school-level Earth science syllabuses

Matrix developed from current syllabuses (and recommendations – US and England)

Statements – derived from the IESO syllabus			IESO	Australia N/C	England N/C	Japan N/C	New Zealand N/C	Norway N/C	Scotland N/C	South Africa N/C	US standards	Portugal N/C	* *US framework*	* *England rec.*	** Frequency	Covered by proposal
		Details of syllabuses	**IESO syllabus** Page nos.	**Australian Curriculum, Science**	**English National Curriculum** S=science, G=geography	**Japanese 'Geoscience basics' and 'Geoscience' syllabuses**	**New Zealand Curriculum in Geoscience**	**Norwegian geoscience syllabus**	**Scottish 'Curriculum for Excellence'**	**South African 'Natural Sciences' & 'Social sciences' syllabuses**	**US science education standards** S = standards, 1996	**Personal communication,** Luis Marques and Clara Vasconcelos	***US science education standards*** *F = Framework, 2012*	***English recommendations to the Department for Education***	**Frequency of statement** F = frequent M = moderate blank = infrequent	**Covered by syllabus proposal** C = core; E = exemplars
Geoscience skills and abilities																
		three dimensional thinking	4									X				
		thinking on different timescales including deep time	4									X	*F2, F3*		M	C
		thinking at different scales, from microscopic to global										X	*F3*			
		cyclic thinking	4									X				
		systems thinking	4									X	*F 3*		M	C
		field skills	4		G, KS3 104, 107					SS 48		X			M	C
		construction of a geological history	4													

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The Geosphere			6	4												
Earth materials	**Minerals**		7	3				S6	S17						M	C
		quartz	7									X				
		orthoclase	7									X				
		plagioclase	7									X				
		biotite	7									X				
		muscovite	7									X				
		garnet	7													
		calcite	7									X				
		clay	7													
		halite	7													
		gypsum	7													
		pyrite	7													
	Soil		7		S, KS2 11				S17					√	M	C
		soils have properties of color and texture, capacity to retain water, and ability to support growth of plants, including those in our food supply								NS 69	S1					
		soil consists of weathered rocks and decomposed organic material from dead plants, animals, and bacteria. Soils are often found in layers								NS 70	S2					E
	Rock		7		S, KS1 5			S6	S17						M	C

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& S, KS2 11														
texture			S, KS2 11					NS 69		X			M	E
permeability			S, KS2 11											
Sedimentary rocks	7	3						NS 70		X		√	F	C
limestone	7									X				
chalk	7													
chert	7													
clay	7													
marl	7													
dolomite	7													
sandstone	7									X				
phosphorite	7													
gypsum	7													
rock salt	7									X				
Igneous rocks	7	3						NS 70		X		√	F	C
granite	7									X				
rhyolite	7													
obsidian	7													
basalt	7									X				
andesite	7													
gabbro	7													
tuff	7													
Metamorphic rocks	7	3						NS		X		√	F	C

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								70						
schist	7									X				
gneiss	7									X				
marble	7													
metaquartzite (quartzite)	7													
Fossils	7											√		
various forms of fossilisation	7									X				
fossils provide evidence about the plants and animals that lived long ago and the nature of the environment at that time								NS 63, 70, 72	S1, S2	X			M	E
mass extinction								NS 65		X				
Rock structures														
Sedimentary textures/ structures/ features	7									X				
layering (bedding)	7			1, 2						X			M	E
graded bedding	7													
cross bedding	7													
ripple marks	7													
discontinuity planes	7													
Igneous textures/ structures/ features	7													
porphyritic	7													
pegmatitic	7													
scoria	7													
volcano	7									X				
lava flow	7									X				
dyke	7													
sill	7													

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Metamorphic textures/ structures/ features	7									X				
foliation	7													
lineation	7													
Structural features	7													
fold	7									X				
fault	7									X				
Earth processes										X				
Sedimentary processes						GX4						√		
weathering			S, KS3 211							X	*F2, F3*	√	M	E
erosion			G, KS2, 3					NS 69		X	*F2, F3*	√	F	E
deposition			G, KS2, 3					NS 69		X				
lithification								NS 69						
landscape formations by glaciers						GX4								
Fossilisation processes	7									X				
Igneous processes			S, KS3 211	2		GX4				X		√	F	C
volcanic activity				1						X				
Metamorphic processes			S, KS3	2		GX4						√	M	C

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					211											
	Deformation processes											X	*F2*			
		stress fields influence rock	7													
		tensional processes	7									X				
		compressional processes	7									X				
		shear processes														
		earthquakes				1,2						X	*F2*			
	Past processes											X				
		Earth processes today are similar to those that occurred in the past. Earth history is also influenced by occasional catastrophes									S2	X				
Geological time																
	Deep time		3, 4	4									*F2*		M	C
		the solar system formed 4.6 billion years ago									S3	X				
		evidence for one- celled forms of life —the bacteria — extends back more than 3.5 billion years									S4	X				
		punctuated by a series of key events										X	*F3*			
	Relative dating						2									
		using rock strata						GX4			S3	X	*F2*	√	F	E
		using fossils						GX4			S3	X	*F2*		M	E
		using tree rings and ice cores											*F2*			
	Absolute dating						2									

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by radioactive decay of isotopes						GX4			S3		*F3*	√	M	E
Structure of the Earth														
Characteristics														
shape and size of the Earth				1						X				
Earth magnetism				1						X				
Layers	6			1					S1	X			M	C
crust										X	*F3*	√	M	C
mantle								NS 71		X	*F3*	√	M	C
core	6							NS 71		X	*F3*	√		
lithosphere								NS 71	S1	X			M	C
evidence for Earth's structure (probes, seismic, magnetic, geological)										X	*F3*			
Earth cycles														
Cyclic processes														
transition between reservoirs where form changes but total amount of matter remains constant	6								S3			√	M	C
feedback (positive and negative)	6										*F3*	√	M	C
tight coupling of systems	6											√		
rates vary from fast to very slow	6	3						NS 69	S1		*F2*		F	E
Earth systems	6	4			2				S3		*F3*	√	F	C
lithosphere	6	4						NS 71			*F3*	√	F	C

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hydrosphere	6	4						NS 71			*F3*	√	F	C
atmosphere	6	4						NS 71			*F3*	√	F	C
biosphere	6	4									*F3*	√	M	C
interactions and cycles within and between Earth's spheres		4										√		
the many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it									S3		*F6*	√	M	E
Earth energy sources	6													
solar energy	6							NS 71	S3	X	*F3*		F	E
internal energy (including radioactive decay)	6								S3		*F3*			
gravitational energy from the Earth's original formation.									S3					
Rock cycle	6		S, KS3 211						S2	X			M	C
Plate tectonic cycle	6	4	S, KS4 225	2						X			F	C
lithospheric plates constantly move at rates of centimetres per year in				1				NS 71	S1	X		√	F	C

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		response to movements in the mantle. Major geological events, such as earthquakes, volcanic eruptions, and mountain building, result from these plate motions.														
		tectonic processes continually generate new ocean seafloor at ridges and destroy old seafloor at trenches											*F3*	√		
		continental rocks (eg >4 billion years old), are generally much older than rocks on the ocean floor (<200 million years old)											*F3*			
		motions of the mantle and its plates occur primarily through thermal convection								NS 71	S3		*F3*	√	M	
		the locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in patterns.								NS 71		X	*F4*	√	M	E
		most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans.										X	*F4*	√	M	E
		major mountain chains form inside continents or near their edges											*F4*	√		
		plate tectonics is the unifying theory that		4									*F4*	√	M	C

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		explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geological history														
	Carbon cycle		3	4					S5		S3			√	M	C
The hydrosphere			8	4												
	Water		8													
		water cycle (transpiration, evaporation, condensation and crystallization, and precipitation as well as downhill flows on land)		3			3		S5	NS 70	S2		*F5*	√	F	C
		the geosphere, hydrosphere, atmosphere and biosphere are tightly coupled	8										*F3*			
		natural water composition is affected by geological processes	8													
		water's unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting points of rocks	8				4						*F5*		M	E

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		water availability is affected by atmospheric and geological processes	8										*F5*			
		the amount of water for human consumption is limited	8													
		water resources need to be carefully managed								NS 70						
		flood	8					GX4						√	M	
		drought			G, KS2, 3			GX4								
	Oceanic water		8													
		oceanic water composition affected by geological processes	8				4									
		the composition of oceanic water evolved over geological time	8											√		
		ocean currents are the result of unequal heating of the Earth and salinity differences	9			1							*F5*	√	M	C
		the ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.				2	2, 4						*F5*		M	E
		tsunamis	8													
		tides														
		storms (hurricanes,	8													

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typhoons)														
The atmosphere	8	4												
Composition	9													
the geosphere, hydrosphere, atmosphere and biosphere are tightly coupled	9													
the composition of the early atmosphere was from gases omitted by volcanic activity	9													
the composition of the atmosphere has evolved over geological time	9		S, KS4 225									√	M	C
evolution of the composition of the atmosphere is tightly linked to evolution of life on Earth	9								S4			√		
the modern atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapour					4		S5	NS 71	S2			√	F	C
the atmosphere protects the earth from harmful radiation and from most objects from outer space that would otherwise strike the Earth's surface								NS 71						
Flow	9													
the foundation for Earth's global climate system is the electromagnetic radiation from the sun as well as its reflection, absorption,				1	2	SS8					*F6*		M	C

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		storage, and redistribution among the atmosphere, ocean, and land systems and this energy's re-radiation into space.														
		Earth's axial tilt causes differential intensity of sunlight on different areas of Earth									S3		*F2*			
		atmospheric flows are the result of unequal heating of the Earth	9			1, 2					S3			√	M	E
	Change															
		climate change	1, 2		G, KS3 106				S5					√	M	C
		global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the Earth's rotation, and static conditions such as the position of mountain ranges and oceans	S3					GX4								
		cyclical changes in the shape of Earth's orbit around the sun, together with changes in the orientation of the planet's axis of rotation, both occurring over tens to					2						*F2*			

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		hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth. These phenomena cause cycles of ice ages and other gradual climate changes														
		greenhouse gases in the atmosphere absorb and retain the energy radiated from land and ocean surfaces, thereby regulating Earth's average surface temperature and keeping it habitable.						S8					*F5*	√	M	C
		climate change can occur when certain parts of Earth's systems are altered. Geological evidence indicates that past climate changes were either sudden changes caused by alterations in the atmosphere; longer term changes (e.g., ice ages) due to variations in solar output, Earth's orbit, or the orientation of its axis; or even more gradual atmospheric changes due to plants and other organisms that captured carbon dioxide and released oxygen. The time scales of these changes											*F6*			

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		varied from a few to millions of years														
		changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate											*F6*			
		if Earth's global mean temperature continues to rise, the lives of humans and other organisms will be affected in many different ways							S5				*F8*			
		global climate models are often used to understand the process of climate change											*F8*			
The biosphere				4												
	Interactions															
		the evolution and proliferation of living things over geological time have in turn changed the rates of weathering and erosion of land surfaces, altered the composition of Earth's soils and atmosphere, and affected the distribution of water in the hydrosphere.	3, 6										*F6*			
	Evolution			5												
		fossils provide evidence for evolution								NS 63				√		
		evolution is shaped by Earth's varying geological											*F7*	√		

Statements – derived from the IESO syllabus			IESO	Australia N/C	England N/C	Japan N/C	New Zealand N/C	Norway N/C	Scotland N/C	South Africa N/C	US standards	Portugal N/C	* *US framework*	* *England rec.*	** Frequency	Covered by proposal
		conditions														
		sudden changes in conditions (e.g., meteor impacts, major volcanic eruptions) have caused mass extinctions, but these changes, as well as more gradual ones, have ultimately allowed other life forms to flourish											*F7*			
		evidence for theories that explain the diversity of life on Earth and evolution		5										√		
Environmental geoscience																
		global distribution of resources depends upon past geological processes												√		
		the environment is part of a cyclic world formed of sub-systems (geosphere, hydrosphere, atmosphere and biosphere) that coexist	2													
		humans are an integral part of the natural system	2		S, KS3 211 & G, KS3 103		4						*F3*		M	C
		all materials, energy, and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways.								NS 72		X	*F7*		M	C
		the effects of human			S,					SS 88		X				

Statements – derived from the IESO syllabus			IESO	Australia N/C	England N/C	Japan N/C	New Zealand N/C	Norway N/C	Scotland N/C	South Africa N/C	US standards	Portugal N/C	* *US framework*	* *England rec.*	** Frequency	Covered by proposal
		activity on the environment			KS4 225											
		explain how crude oil and natural gas have come about and how these substances are used						S8	S4							
		all forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks, as well as benefits						SS9	S4	SS 92/3		X	*F7*		F	C
		sustainable development		3	S, KS3 212 & G, KS3 103			S8	S4, G6	NS 58/9, SS 92		X	*F8*	√	F	C
		renewable and non-renewable resources		3	S, KS3, 212			S8	S4	NS 67, 72			*F6*	√	F	C
		environmental problem identification and suggestion of solutions	4	2					G6			X	*F8*		F	C
		the cause of natural disasters, including earthquakes, tsunamis and volcanic eruptions		2			2, 4	GX4	G6	SS 89		X		√	F	C
		natural hazard forecasting and mitigation	5					GX4					*F7*		M	C
The solar system												X				
	Planetary system		10				3									
		the star called the sun is changing and will burn out									S3		*F1*			

Statements – derived from the IESO syllabus			IESO	Australia N/C	England N/C	Japan N/C	New Zealand N/C	Norway N/C	Scotland N/C	South Africa N/C	US standards	Portugal N/C	* *US framework*	* *England rec.*	** Frequency	Covered by proposal
		over a life span of approximately 10 billion years														
		Earth rotation, day/night, daily/seasonal changes, phases of moon		1, 3		2		S4, S6	S6	NS 69	S1, S2, S3		*F2*	√	F	C
		eclipses		3							S2		*F2*		M	C
		tides									S2		*F2*			
		Earth systems are a subset of planetary systems	10													
		energy balances of planets include external (solar) energy and internal energy	10													
		the solar system has evolved over time			S, KS4 225											

* Note: *Curriculum recommendations – not yet implemented*
** Note: F = frequent (more than 4); M = moderate (3 or 4); blank = infrequent (2 or less)

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