Topic	The IASPEI standard nomenclature of seismic phases
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Version	September 2013; **DOI: 10.2312/GFZ.NMSOP-2_IS_2.1**

1 Introduction

A Working Group (WG) on Standard Phase Names was set up by the IASPEI Commission on Seismological Observation and Interpretation in 2001. The working group was chaired by D. A. Storchak of the ISC. Members of the group were R. D. Adams, P. Bormann, R. E. Engdahl, J. Havskov, B. L. N. Kennett and J. Schweitzer. The working group has put together a modified standard nomenclature of seismic phases, which was meant to be concise, consistent and self-explanatory on the basis of agreed rules. The result is not a complete list of all phases. The list is not meant to satisfy specific requirements of seismologists to name various phases used in a particular type of research. Instead, the new phase list aims at inviting data analysts and other users to ensure an expanded standardized data reporting and exchange. This will result in a broader and unambiguous database for research and practical applications. At the same time the attached list and its principles outlined below may be a useful guidance when proposing names to previously unknown seismic phases.

After numerous consultations with the seismological community, the Standard Seismic Phase List was finalized and adopted by the CoSOI/IASPEI at its meeting in Sapporo on July 04, 2003. The original draft list of standard seismic phase names was first published as part of the New Manual of Seismological Observatory Practice (Storchak et al., 2002). Later on, the list was published in the Seismological Research Letters (Storchak et al., 2003). Since then various updates to the list were required due to progress in observational seismology and relevant changes in other observational standards. These changes were accommodated in a contribution by Storchak et al. (2011) to the Encyclopedia of Solid Earth Geophysics. The current amended version of IS 2.1 takes all these updates into account. Moreover, it aims at unifying some wording in the definitions. The List should be used as a guide to identify such phases in real seismic records by taking into account additional resources provided in DS11.1 to DS11.4 of the NMSOP-2.

The new IASPEI nomenclature partially modifies and complements the earlier one published in the last edition of the Willmore (1979) Manual of Seismological Observatory Practice and in the Summaries of the Bulletin of the International Seismological Centre (2010). It is more in tune with phase definitions according to modern Earth and travel-time models (see Chapter 2, section 2.7) and the definition of pronounced travel-time branches, of core phases in particular (see manual sections 11.5.2.4 and 11.5.3). As opposed to former practice, the WG tried to make sure that a phase name generally reflects the type of the wave and the path it has traveled. Accordingly, symbols for characterizing onset quality, polarity etc. are no longer part of the phase name. Also, the WG acknowledges that there exist several types of seismic phases, particularly among crustal phases, that are common in some regions yet never or rarely found in other regions, such as, e.g., Pb (P*), PnPn, PbPb, etc. The names and definitions of acoustic and hydroacoustic phases and amplitude measurement are likely to be reviewed based on the results of recent developments and new analysis practices being established.

The extended list of phase names, as presented below in section 5, accounts for significantly increased detection capabilities of modern seismic sensors and sensor arrays, especially for weak phases that were rarely found using the classical analog records. It also accounts for improved possibilities of proper phase identification by means of digital multi-channel data processing such as frequency-wavenumber (f-k) analysis and polarization filtering, by modeling the observations with synthetic seismograms or by showing on the records the theoretically predicted onset times of phases. Furthermore, limitation of classical formats for wave parameter reporting to international data centers, such as the Telegraphic Format (TF), which allowed only the use of capital letters and numbers, are no longer relevant in times of data exchange via the Internet. Finally, the newly adopted IASPEI Seismic Format (ISF; see http://www.isc.ac.uk/standards/isf/download/isf.pdf, Chapter 10, section 10.2.5 and IS 10.2) is much more flexible then the old formats accepted by the NEIC, ISC and other data centers. It also allows reporting, computer parsing and archiving of all phases, including previously uncommon ones. The ISF also accepts complementary parameters such as onset quality, signal-to-noise ratio, measured backazimuth and slowness, amplitudes and periods of other phases in addition to P and surface waves, for components other than vertical ones, and for non-standard response characteristics.

This increased flexibility of the parameter-reporting format requires improved standardization, which limits an uncontrolled growth of incompatible and ambiguous parameter data. Therefore, the WG agreed on certain rules. They are outlined below prior to the listing of standardized phase names. In order to ease the understanding of verbal definitions of the phase names and ray diagrams are presented. The ray diagrams have been calculated for local seismic sources on the basis of an average one-dimensional two-layer crustal model and for regional and teleseismic sources by using the global, radial symmetrical Earth model *ak135* (Kennett et al., 1995; see also Fig. 2.79).

Before elaborating short-cut seismic phase names one should agree first on the *language* to be used and its rules. As in any other language we need a suitable alphabet (here Latin letters), numbers (here Arabic numbers and + and - signs), an *orthography*, which regulates, e.g., the use of capital and lower case letters, and a *syntax*, i.e., rules of correct order and mutual relationship of the language elements. One should be aware, however, that the seismological nomenclature will inevitably develop exceptions to the rules, as any historically developed language, and also depending on the context in which it is used. Although not fully documented below, some exceptions will be mentioned. Note that our efforts are mainly aimed at standardized names to be used in international data exchange so as to build up unique, unambiguous global databases for research. Many of the exceptions to the rules are related to specialized, mostly local research applications. The identification of related seismic phases often requires specialized procedures of data acquisition and processing, which are not part of seismological routine data analysis. Also, many of these *exceptional* phases are rarely or never used in seismic event location, magnitude determination, source mechanism calculations etc., which are the main tasks of international data centers. Below, we focus therefore on phases, which are particularly important for seismological data centers as well as for the refinement of regional and global Earth models on the basis of widely exchanged and accumulated parameter readings from such phases. In addition, we added for some phase definitions references to which the particular phase names can be traced back.

2 Standard letters, signs and syntax used for describing seismic phases

2.1 Capital letters

Individual capital letters that stand for primary types of seismic *body waves* such as:

- P: longitudinal wave that has traveled through the Earth's crust and mantle, from *undae primae* (Latin) = first waves (Borne, 1904);
- K: longitudinal wave that has traveled through the Earth's outer core, K, from Kern (German) = core (Sohon, 1932; Bastings, 1934);
- I: longitudinal wave that has traveled through the Earth's inner core (Jeffreys and Bullen, 1940);
- S: transverse wave that has traveled through the Earth's crust and mantle, from *undae secundae* (Latin) = second waves (Borne, 1904);
- T: wave that has partly traveled as sound wave in the sea, from *undae tertiae* = third waves (Linehan, 1940);
- J: transverse wave that has traveled through the Earth's inner core (Bullen, 1946).

Exceptions:

- A **capital letter N** used in the nomenclature does not stand for a phase name but rather for the number of legs traveled (or N-1 reflections made) before reaching the station. N should usually follow the phase symbol to which it applies. For examples see syntax below.
- The **lower case letters p and s** may stand, in the case of seismic events below the Earth's surface, for the relatively short **upgoing leg** of P or S waves, which continue, after reflection and possible conversion at the free surface, as downgoing P or S wave. Thus seismic *depth phases* (e.g., pP, sP, sS, pPP, sPP, pPKP, etc.) are uniquely defined. The identification and reporting of such phases is of utmost importance for source depth determination (Scrase, 1931; Stechschulte, 1932; Gutenberg et al., 1933; Macelwane et al., 1933).
- Many researchers working on detailed investigations of crustal and upper-mantle discontinuities denote both the up- and downgoing short legs of converted or multiply reflected P and S phases as lower case letters p and s, respectively.

Individual or double capital letters that stand for *surface waves* such as:

- L: (relatively) long-period surface wave, unspecified, from *undae longae* (Latin) = long waves (Borne, 1904);
- R: Rayleigh waves (short- to very long-period waves in crust and upper mantle) (Angenheister, 1921);
- Q: Love waves, from Querwellen (German) = transverse waves (Angenheister, 1921);
- G: (very long-period) global (mantle) Love waves, firstly observed and reported by Gutenberg and Richter (1934); in honor of Gutenberg, Byerly proposed the usage of G for Gutenberg for these waves Richter (1958);
- LR: long-period Rayleigh waves, usually relating to the Airy-phase maximum in the surface wave train;
- LQ: long-period Love waves.
- PL: fundamental leaking mode following P onsets, firstly observed and reported by Somville (1930, 1931)

2.2 Lower case letters and signs

Single lower case letters generally specify in which part of Earth's crust or upper mantle in which a phase has its *turning point* or at which discontinuity it has been *reflected and/or eventually converted*:

- g (following a general phase name): characterizes waves "bottoming" (i.e., having their turning point in the case of P- or S-body waves) or just travel (surface waves) within the upper ("granitic") Earth's crust (e.g., Pg, Sg; Rg), (Jeffreys, 1926);
- b (following a general phase name): characterizes body waves "bottoming" in the lower ("basaltic") Earth's crust (Jeffreys, 1926) (e.g., Pb, Sb; alternative names for these phases are P*, S*, (Conrad, 1925)); also used for phases radiated directly to the Earth's surface from events in the lower crust;
- n (following a general phase name): characterizes a P or S wave that is "bottoming" in the Earth's uppermost mantle or is traveling as head wave below the

Mohorovičić (Moho) discontinuity (e.g., Pn, Sn), introduced after Andrija Mohorovičić discovered the Earth's crust and separated the crustal travel-time curve from the normal (=n) mantle phase (Mohorovičić, 1910); also used for phases radiated directly to the Earth's surface from events in the uppermost mantle;

- m: (upward) reflections from the *outer side* of the Moho (e.g., PmP, SmS);
- c: reflections from the *outer side* of the core-mantle boundary (CMB), usage proposed by James B. Macelwane (see Gutenberg, 1925);
- i: reflections from the *outer side* of the inner core boundary (ICB);
- z: reflections from a discontinuity (other than free surface, CMB or ICB) at depth z (measured in km). Upward reflections from the *outer side* of the discontinuity *may* additionally be complemented by a + sign (e.g., P410+P; this, however, is not compulsory) while downward reflections from the *inner side* of the discontinuity *must* be complemented by a – sign (e.g., P660-P).

An exception from these rules is the use of lowercase p or s to indicate arrivals of longitudinal or transverse waves that were from a source below the Earth's surface first radiated to go up toward the free surface to be reflected / converted back into the Earth as normal P or S waves (see near source surface reflections and conversions section of the phase list below).

To call phases radiated directly to the Earth's surface in the near source region from events in the lower crust (Conrad discontinuity) Pb and from below the Moho Pn is a quite pragmatic decision, which helps analysts and source location programs to separate the different branches of the travel-time curves.

Double lower case letters following a capital letter phase name indicate the travel-time branch to which this phase belongs. Due to the geometry and velocity structure of the Earth the same type of seismic wave may develop a triplication of its travel-time curve with different, in some cases well separated branches (see Chapter 2, Fig. 2.32). Thus it is customary to differentiate between different branches of core phases and their multiple reflections at the free surface or the CMB. Examples are PKPab, PKPbc, PKPdf, SKSac, SKKSac, etc.. The separation of the different PKP branches with letters ab, bc and df was introduced by Jeffreys and Bullen (1940).

Three lower case letters may follow a capital letter phase name in order to specify its character, e.g., as a forerunner (pre) to the main phase, caused by scattering (e.g., PKPpre) or as a diffracted wave extending the travel-time branch of the main phase into the outer core shadow (e.g., Pdif in the outer core shadow for P).

2.3 Syntax of generating complex phase names

Due to refraction, reflection and conversion in the Earth most of phases have a complex path history before they reach the station. Accordingly, most phases cannot be described by a single capital letter code in a self-explanatory way. By combining the capital and lower case letters as mentioned above, one can describe the character of even rather complex refracted, reflected or converted phases. The order of symbols (syntax) regulates the sequence of phase legs due to refraction, reflection and conversion events in time (from left to right) and in space.

3 Examples for creating complex standard phase names

3.1 Refracted and converted refracted waves

- PKP is a pure refracted longitudinal wave. It has traveled the first part of its path as P through crust and mantle, the second through the outer core, and the third again as P through mantle and crust. An alternative name for PKP is P' (Angenheister, 1921), which should be read as "P prime".
- PKIKP (alternative to PKPdf) is also a pure refracted longitudinal wave too. It has traveled as P the first part of its path through crust and mantle, the second through the outer core, the third through the inner core, and the fourth and fifth parts back again through outer core and mantle/crust.
- SKS is a converted refracted wave. It has traveled as a shear wave through crust and mantle, being converted into a longitudinal P wave when refracted into the outer core and converted back again into an S wave when entering the mantle.
- SKP or PKS are converted refracted waves with only one conversion from S to P when entering the core or from P to S when leaving the core, respectively.

3.2 Pure reflected waves

- In the case of (downward only) reflections at the free surface or from the inner side of the CMB, the phase symbol is just repeated, e.g., PP, SS (Geiger, 1909), PPP, SSS, KK, KKK etc.
- In the case of (upward) reflections from the outer side of the Moho, the CMB, or the ICB, this is indicated by inserting between the phase symbols m, c or i, respectively, between the phase symbols, e.g., PmP, PcP, ScS; PKiKP.
- Reflections from any other discontinuity in mantle or crust at depth z may be from the inner side (-; i.e., downward back into the mantle) or from the outer side (+; i.e., back towards the surface). To differentiate between these two possibilities, the sign has to follow z (or the respective number in km); for example, P410+P or P660-P.
- To abbreviate names of multi-leg phases due to repeated reflections, one can also write PhasenameN. This kind of abbreviation, is rather customary in the case of multiple phases with long phase names such as PmP2 for PmPPmP (free-surface reflection of PmP), SKS2 for SKSSKS (alternative name for S'2, the free-surface reflection of SKS), PKP3 for PKPPKPPKP (double free-surface reflection of PKP; alternative name to P'3) or P4KP for PKKKKP (triple reflection of P at the inner side of the CMB).

Note 1: PKP2 = PKPPKP are now alternative names for P'2 or P'P', respectively. This should not be mistaken for the *old* name PKP2 for PKPab.

Note 2: In the case of multiple reflections from the inner side of the CMB the WG followed the established tradition of placing the number N not after but *in front* of the related phase symbol K.

3.3 Reflected waves with conversion at the reflection point

In the case that a phase changes its character from P to S, or vice versa, one writes:

- PS (first leg P, second leg S) or SP (first leg P, second leg S) in the case of reflection/conversion from the free surface downward into the mantle (Geiger and Gutenberg, 1912a, 1912b);
- PmS or SmP, respectively, for reflection/conversion from the outer side of the Moho;
- PcS or ScP for reflection/conversion from the outer side of the CMB;
- Pz+S or Sz-P for reflection/conversion from the outer (+) side or inner (-) side, respectively, of a discontinuity at depth z. Note that the - is compulsory, the + not.

In this context it is worth mentioning that mode conversion is impossible for reflections from the inner side of the CMB back into the outer core because the liquid outer core does not allow the propagation of S waves.

The WG determined the new IASPEI standard phase names along these lines and rules. Where these deviate from other traditionally used names the latter are given as well. Either, the traditional names are still acceptable *alternative names* (alt) or they are now *old names* (old), which should no longer be used.

4 Ray-paths diagrams for some of the IASPEI standard phases

In this section we show ray paths through the Earth for most of the mentioned phases. The three figures for crustal phases are just sketches showing the principal ray paths in a two-layer crust. The rays in all other figures were calculated by using the ray picture part of the WKBJ3 code (Chapman, 1978; Dey-Sarkar and Chapman, 1978); as velocity model we chose the standard Earth model *ak135* (Kennett et al., 1995). For some types of P and S phases the ray paths through the Earth are very similar because the velocity ratio v_P/v_S does not change enough to give very different ray pictures. In these cases, we calculated only the ray paths for the P-type ray (i.e., P, Pdif, pP, PP, P3, PcP, PcP2, P660P and P660-P) and assume that the corresponding ray paths of the respective S-type phases are very similar. To show the different ray paths for phases with similar phase names, we show on many figures rays leaving the source once to the left and once to the right in different colors. The three most important discontinuities inside the Earth are indicated as black circles (i.e., the border between upper and lower mantle, the CMB, and the ICB).

4.1 Seismic rays of crustal phases

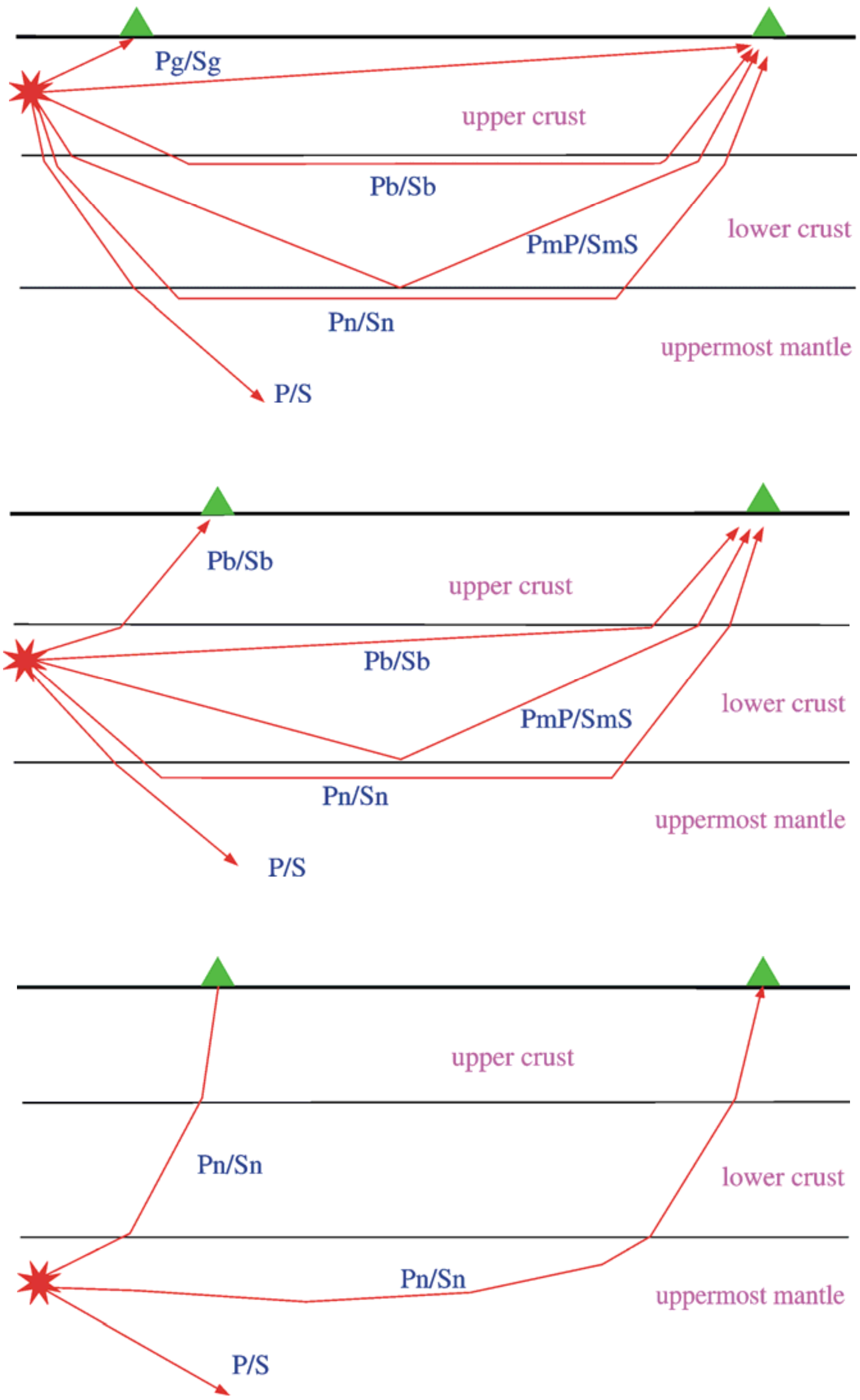


Figure 1 Seismic rays of „crustal phases“ observed in the case of a two-layer crust in local and regional distance ranges (0° < D < about 20°) from the seismic source in the: a) upper crust; b) lower crust; and c) uppermost mantle.

4.2 Seismic rays of mantle phases

Note: The density of seismic rays arriving at a given location is proportional to the relative amplitude of the respective seismic phase observed at this location.

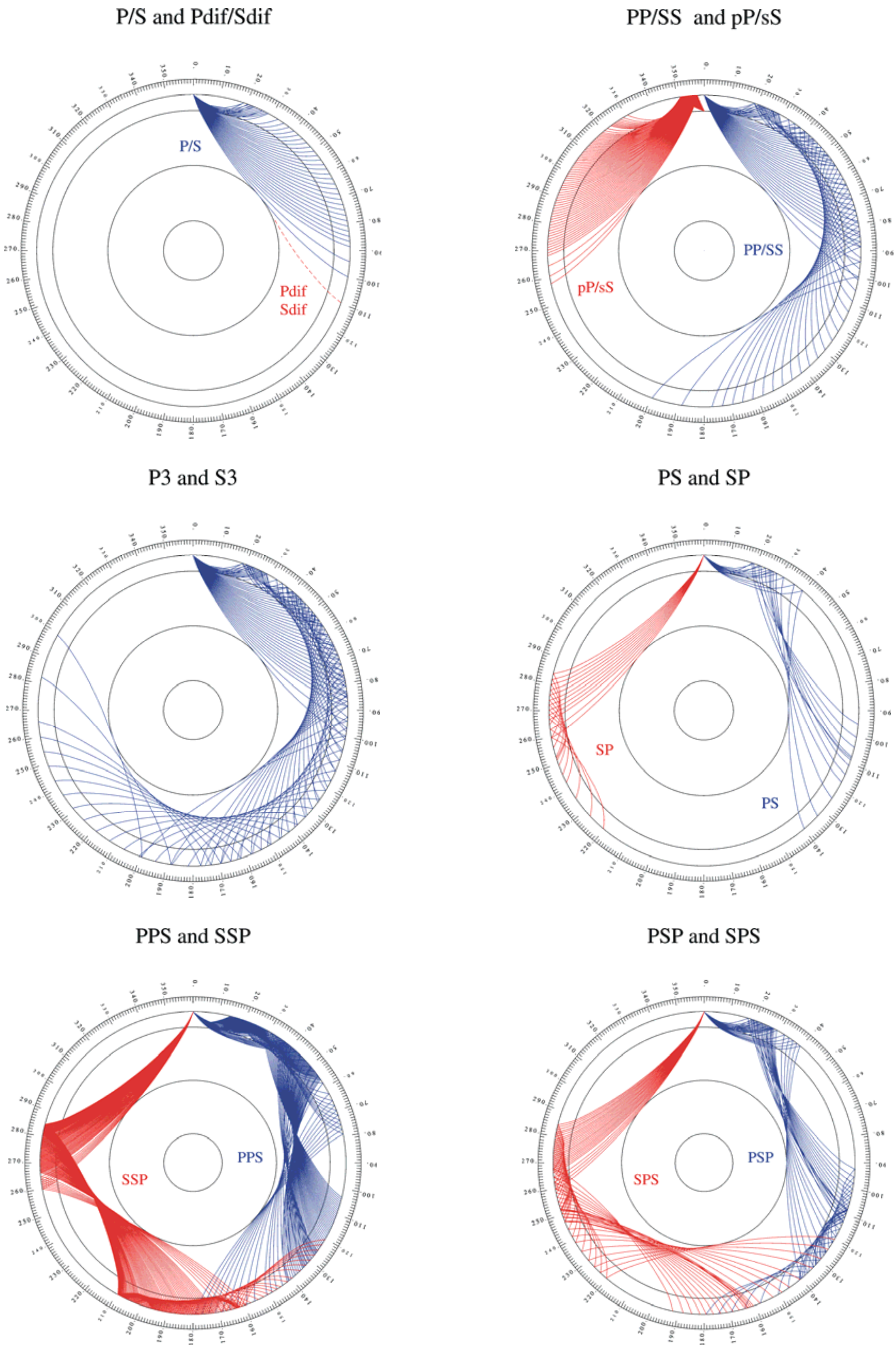
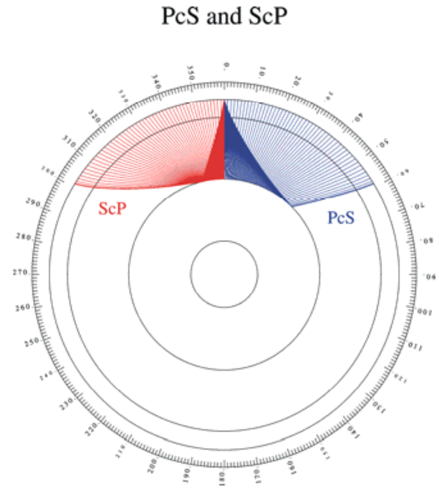
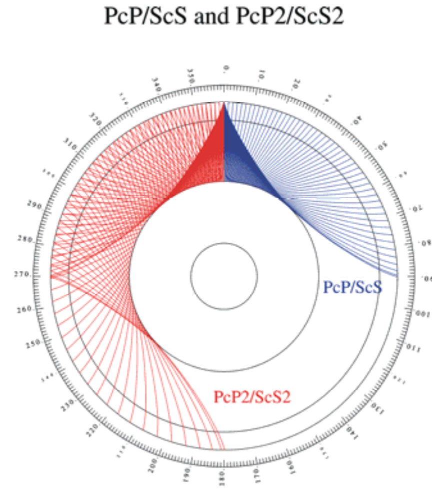


Figure 2 Mantle phases observed at the teleseismic distance range D > about 20°.





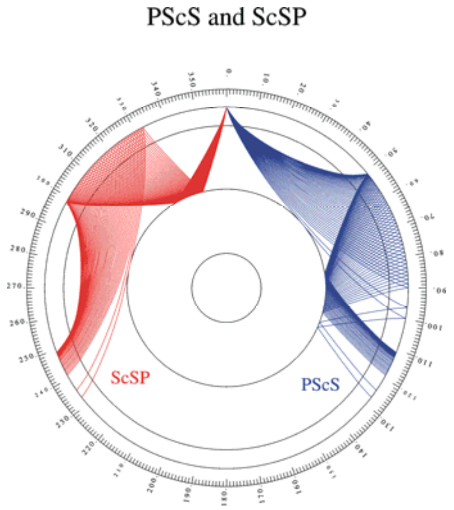


Figure 3 Reflections from the Earth’s core.

4.3 Seismic rays of phases travelling through the Earth’s core

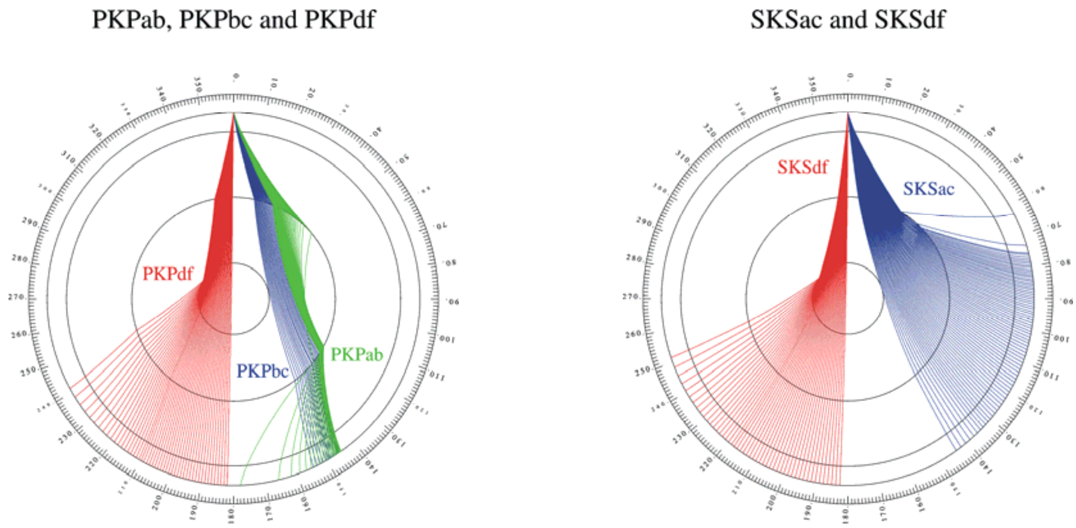


Figure 4 Seismic rays of direct core phases

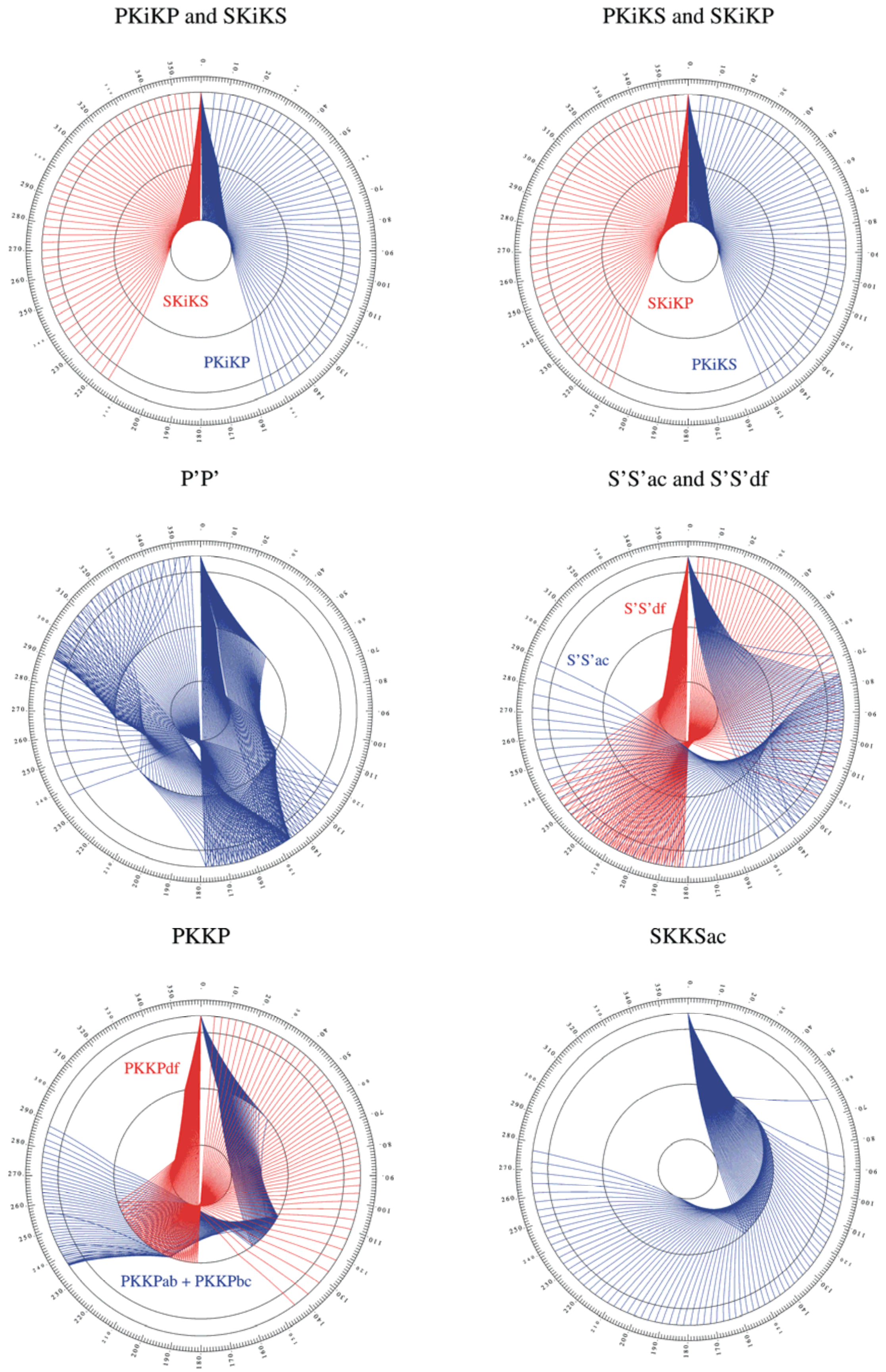


Figure 5 Seismic rays of single-reflected core phases

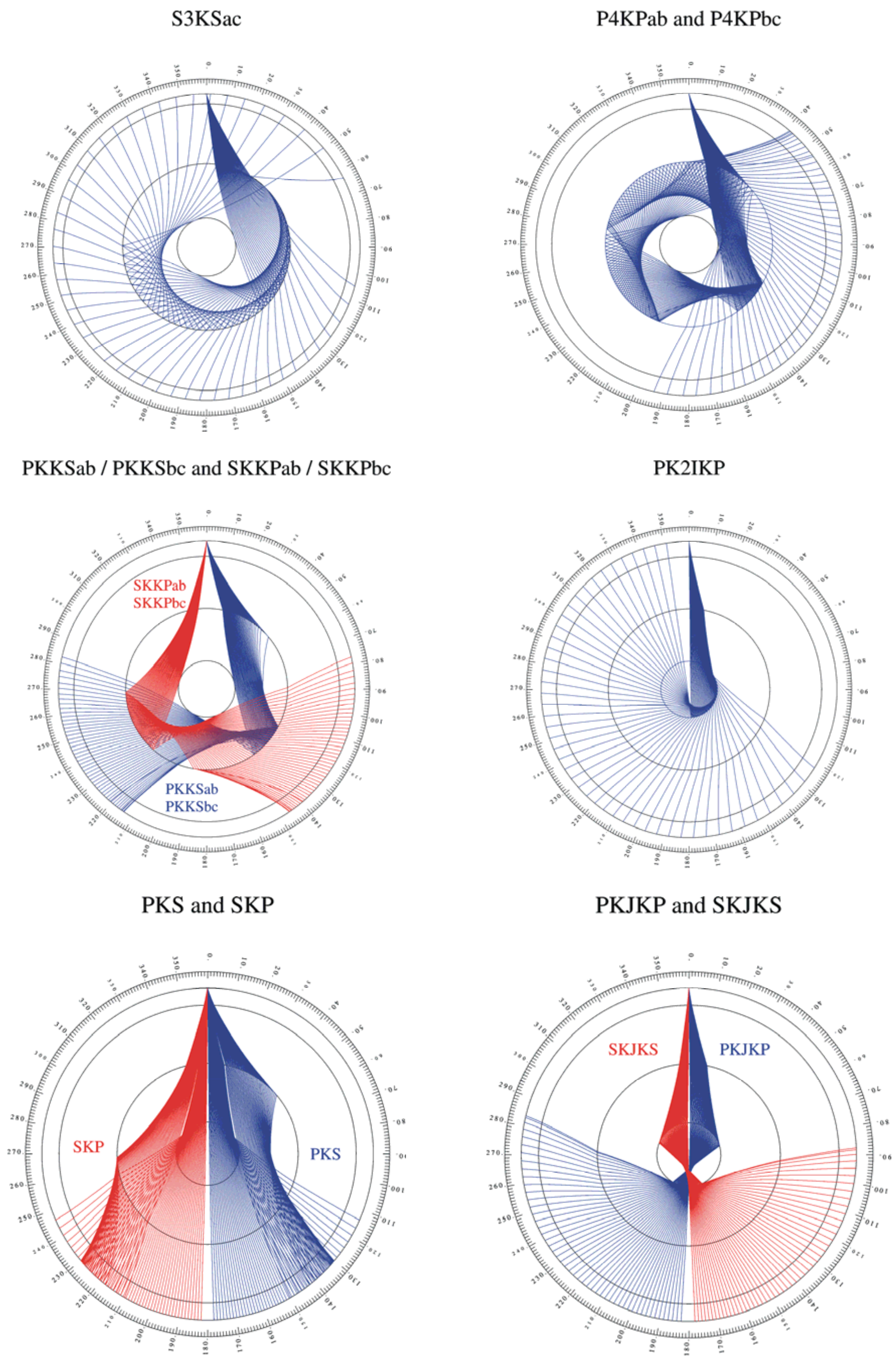


Figure 6 Seismic rays of multiple-reflected and converted core phases.

5 IASPEI Standard Seismic Phase List

5.1 CRUSTAL PHASES (For ray traces see Figure 1; for more examples see Chapter 2, section 2.6.1; Chapter 11, section 11.5.1, DS 11.1 and EX 11.1)

Pg	At short distances, either an upgoing P wave from a source in the upper crust or a P wave bottoming in the upper crust. At larger distances also arrivals caused by multiple P-wave reverberations inside the whole crust with a group velocity around 5.8 km/s
Pb	(alt: P*) Either an upgoing P wave from a source in the lower crust or a P wave bottoming in the lower crust
Pn	Any P wave bottoming in the uppermost mantle or an upgoing P wave from a source in the uppermost mantle
PnPn	Pn free-surface reflection
PgPg	Pg free-surface reflection
PmP	P reflection from the outer side of the Moho
PmPN	PmP multiple free-surface reflection; N is a positive integer. For example, PmP2 is PmPPmP
PmS	P to S reflection/conversion from the outer side of the Moho
Sg	At short distances, either an upgoing S wave from a source in the upper crust or an S wave bottoming in the upper crust. At larger distances also, arrivals caused by superposition of multiple S-wave reverberations and SV to P and/or P to SV conversions inside the whole crust
Sb	(alt: S*) Either an upgoing S wave from a source in the lower crust or an S wave bottoming in the lower crust
Sn	Any S wave bottoming in the uppermost mantle or an upgoing S wave from a source in the uppermost mantle
SnSn	Sn free-surface reflection
SgSg	Sg free-surface reflection
SmS	S reflection from the outer side of the Moho
SmSN	SmS multiple free-surface reflection; N is a positive integer. For example, SmS2 is SmSSmS
SmP	S to P reflection/conversion from the outer side of the Moho
Lg	A wave group observed at larger regional distances and caused by superposition of multiple S-wave reverberations and SV to P and/or P to SV conversions inside the whole crust. The maximum energy travels with a group velocity around 3.5 km/s
Rg	Short-period crustal Rayleigh wave

5.2 MANTLE PHASES (record and ray tracing examples see Chapter 2, section 2.6.2; Chapter 11, section 11.5.2; DS 11.2; EX 11.2 and animations from 42° up to 152° via IS 11.3)

P	A longitudinal wave, bottoming below the uppermost mantle; also an upgoing longitudinal wave from a source below the uppermost mantle
PP	Free-surface reflection of a P wave leaving a source downward

PS	P, leaving a source downward, reflected as an S at the free surface. At shorter distances the first leg is represented by a crustal P wave
PPP	Analogous to PP
PPS	PP which is converted to S at the second reflection point on the free surface; travel time matches that of PSP
PSS	PS reflected at the free surface
PcP	P reflection from the core-mantle boundary (CMB)
PcS	P converted to S when reflected from the CMB
PcPN	PcP reflected from the free surface N-1 times; N is a positive integer. For example PcP2 is PcPPcP
Pz+P	(alt: PzP) P reflection from outer side of a discontinuity at depth z; z may be a positive numerical value in km. For example, P660+P is a P reflection from the top of the 660 km discontinuity
Pz-P	P reflection from inner side of a discontinuity at depth z. For example, P660-P is a P reflection from below the 660 km discontinuity, which means it is precursory to PP
Pz+S	(alt: PzS) P converted to S when reflected from outer side of a discontinuity at depth z
Pz-S	P converted to S when reflected from inner side of a discontinuity at depth z
PScS	P (leaving a source downward) to ScS reflection at the free
Pdif	(old: Pdiff) P diffracted along the CMB in the mantle
S	Shear wave, bottoming below the uppermost mantle; also an upgoing shear wave from a source below the uppermost mantle
SS	Free surface reflection of an S wave leaving a source downward
SP	S, leaving a source downward, reflected as P at the free surface. At shorter distances, the second leg is represented by a crustal P wave.
SSS	Analogous to SS
SSP	SS converted to P when reflected from the free surface; travel time matches that of SPS
SPP	SP reflected at the free surface
ScS	S reflection from the CMB
ScP	S converted to P when reflected from the CMB
ScSN	ScS multiple free-surface reflection; N is a positive integer. For example ScS2 is ScSScS
Sz+S	(alt: SzS) S reflection from outer side of a discontinuity at depth z; z may be a positive numerical value in km. For example S660+S is an S reflection from the top of the 660 km discontinuity.
Sz-S	S reflection from inner side of a discontinuity at depth z. For example, S660-S is an S reflection from below the 660 km discontinuity, which it is precursory to SS
Sz+P	(alt: SzP) S converted to P when reflected from outer side of a discontinuity at depth z
Sz-P	S converted to P when reflected from inner side of a discontinuity at depth z
ScSP	ScS to P reflection at the free surface
Sdif	(old: Sdiff) S diffracted along the CMB in the mantle

5.3 CORE PHASES (record examples see Chapter 2, section 2.6.2; Chapter 11, section 11.5.2, DS 11.3, EX 11.3 and animation files 5 and 6-10 via IS 11.3)

PKP	(alt: P') unspecified P wave bottoming in the core
PKPab	(old: PKP2) P wave bottoming in the upper outer core; ab indicates the retrograde branch of the PKP caustic
PKPbc	(old: PKP1) P wave bottoming in the lower outer core; bc indicates the prograde branch of the PKP caustic
PKPdf	(alt: PKIKP) P wave bottoming in the inner core
PKPpre	(old: PKhKP) a precursor to PKPdf due to scattering near or at the CMB
PKPdif	P wave diffracted at the inner core boundary (ICB) in the outer core
PKS	Unspecified P wave bottoming in the core and converting to S at the CMB
PKSab	PKS bottoming in the upper outer core
PKSbc	PKS bottoming in the lower outer core
PKSdf	PKS bottoming in the inner core
P'P'	(alt: PKPPKP) Free-surface reflection of PKP
P'N	(alt: PKPN) PKP reflected at the free surface N-1 times; N is a positive integer. For example P'3 is P'P'P'
P'z-P'	PKP reflected from inner side of a discontinuity at depth z outside the core, which means it is precursory to P'P'; z may be a positive numerical value in km
P'S'	(alt: PKPSKS) PKP converted to SKS when reflected from the free surface; other examples are P'PKS, P'SKP
PS'	(alt: PSKS) P (leaving a source downward) to SKS reflection at the free surface
PKKP	Unspecified P wave reflected once from the inner side of the CMB
PKKPab	PKKP bottoming in the upper outer core
PKKPbc	PKKP bottoming in the lower outer core
PKKPdf	PKKP bottoming in the inner core
PNKP	P wave reflected N-1 times from inner side of the CMB; N is a positive integer
PKKPpre	a precursor to PKKPdf due to scattering near the CMB
PKiKP	P wave reflected from the inner core boundary (ICB)
PKNIKP	P wave reflected N-1 times from the inner side of the ICB
PKJKP	P wave traversing the outer core as P and the inner core as S
PKKS	P wave reflected once from inner side of the CMB and converted to S at the CMB
PKKSab	PKKS bottoming in the upper outer core
PKKSbc	PKKS bottoming in the lower outer core
PKKSdf	PKKS bottoming in the inner core
PcPP'	(alt: PcPPKP) PcP to PKP reflection at the free surface; other examples are PcPS', PcSP', PcSS', PcPSKP, PcSSKP
SKS	(alt: S') unspecified S wave traversing the core as P
SKSac	SKS bottoming in the outer core
SKSdf	(alt: SKIKS) SKS bottoming in the inner core
SPdifKS	(alt: SKPdifS) SKS wave with a segment of mantle-side Pdif at the source and/or the receiver side of the ray path
SKP	Unspecified S wave traversing the core and then the mantle as P
SKPab	SKP bottoming in the upper outer core
SKPbc	SKP bottoming in the lower outer core
SKPdf	SKP bottoming in the inner core

S'S'	(alt: SKSSKS) Free-surface reflection of SKS
S'N	SKS reflected at the free surface N-1 times; N is a positive integer
S'z-S'	SKS reflected from inner side of a discontinuity at depth z outside the core, which means it is precursory to S'S'; z may be a positive numerical value in km
S'P'	(alt: SKSPKP) SKS converted to PKP when reflected from the free surface; other examples are S'SKP, S'PKS
S'P	(alt: SKSP) SKS to P reflection at the free surface
SKKS	Unspecified S wave traversing the core as P with one reflection from inner side of the CMB
SKKSac	SKKS bottoming in the outer core
SKKSdf	SKKS bottoming in the inner core
SNKS	S wave traversing the core as P, reflected N-1 times from inner side of the CMB; N is a positive integer
SKiKS	S wave traversing the outer core as P and reflected from the ICB
SKJKS	S wave traversing the outer core as P and the inner core as S
SKKP	S wave traversing the core as P with one reflection from the inner side of the CMB and then continuing as P in the mantle
SKKPab	SKKP bottoming in the upper outer core
SKKPbc	SKKP bottoming in the lower outer core
SKKPdf	SKKP bottoming in the inner core
ScSS'	(alt: ScSSKS) ScS to SKS reflection at the free surface; other examples are ScPS', ScSP', ScPP', ScSSKP, ScPSKP

5.4 NEAR SOURCE SURFACE REFLECTIONS (Depth phases); also see Figure 10 in Chapter 2, section 2.6.3, several examples in DS 11.2 and 11.3 and the animation files 4 and 6 in IS 11.3

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pPy	All P-type onsets (Py) as defined above, which resulted from reflection of an upgoing P wave at the free surface or an ocean bottom; WARNING: The character "y" is only a wild card for any seismic phase, which could be generated at the free surface. Examples are: pP, pPKP, pPP, pPcP etc
sPy	All Py resulting from reflection of an upgoing S wave at the free surface or an ocean bottom. For example: sP, sPKP, sPP, sPcP etc.
pSy	All S-type onsets (Sy) as defined above, which resulted from reflection of an upgoing P wave at the free surface or an ocean bottom. For example: pS, pSKS, pSS, pScP, etc.
sSy	All Sy resulting from reflection of an upgoing S wave at the free surface or an ocean bottom. For example: sSn, sSS, sScS, sSdif, etc.
pwPy	All Py resulting from reflection of an upgoing P wave at the ocean's free surface
pmPy	All Py resulting from reflection of an upgoing P wave from the inner side of the Moho

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5.5 SURFACE WAVES

L	Unspecified long-period surface wave
LQ	Love wave
LR	Rayleigh wave
G	Mantle wave of Love type
GN	Mantle wave of Love type; N is integer and indicates wave packets traveling along the minor arcs (odd numbers) or major arc (even numbers) of the great circle
R	Mantle wave of Rayleigh type
RN	Mantle wave of Rayleigh type; N is integer and indicates wave packets traveling along the minor arcs (odd numbers) or major arc (even numbers) of the great circle
PL	Fundamental leaking mode following P onsets generated by coupling of P energy into the waveguide formed by the crust and upper mantle
SPL	S wave coupling into the PL waveguide; other examples are SSPL, SSSPL

5.6 ACOUSTIC PHASES

H	A hydroacoustic wave from a source in the water, which couples in the ground
HPg	H phase converted to Pg at the receiver side
HSg	H phase converted to Sg at the receiver side
HRg	H phase converted to Rg at the receiver side
I	An atmospheric sound arrival, which couples in the ground
IPg	I phase converted to Pg at the receiver side
ISg	I phase converted to Sg at the receiver side
IRg	I phase converted to Rg at the receiver side
T	A tertiary wave. This is an acoustic wave from a source in the solid Earth, usually trapped in a low velocity oceanic water layer called the SOFAR channel (SOund Fixing And Ranging)
TPg	T phase converted to Pg at the receiver side
TSg	T phase converted to Sg at the receiver side
TRg	T phase converted to Rg at the receiver side

5.7 UNIDENTIFIED ARRIVALS
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x	(old: i, e, NULL) unidentified arrival
rx	(old: i, e, NULL) unidentified regional arrival
tx	(old: i, e, NULL) unidentified teleseismic arrival
Px	(old: i, e, NULL, (P), P?) unidentified arrival of P-type
Sx	(old: i, e, NULL, (S), S?) unidentified arrival of S-type

5.8 AMPLITUDE MEASUREMENT PHASES

The following set of amplitude measurement names refers to the IASPEI (2013) Magnitude Standard, compliance to which is indicated by the presence of leading letter I. The absence of leading letter I indicates that a measurement is non-standard. Letter A indicates a measurement in nm made on a displacement seismogram, whereas letter V indicates a measurement in nm/s made on a velocity seismogram. All amplitude measurements for standard magnitudes, with the exception for ML, are made on vertical-component seismic records. For details on the measurement standards, e.g., on the required response simulation before measuring band-limited magnitudes like mb, mb(Lg), ML or Ms(20), the related measurements of periods, of the measurement time windows as well as on the relationship between standard and classical magnitudes see IS 3.3.

IAML	Displacement amplitude measured according to the IASPEI standard for local magnitude ML
IAMs_20	Displacement amplitude measured according to IASPEI standard for surface-wave magnitude Ms(20)
IVMs_BB	Velocity amplitude measured according to IASPEI standard for broadband surface-wave magnitude Ms(BB)
IAmb	Displacement amplitude measured according to IASPEI standard for short-period teleseismic body-wave magnitude mb
IVmB_BB	Velocity amplitude measured according to IASPEI standard for broadband teleseismic body-wave magnitude mB(BB)
IAmb_Lg	Displacement amplitude measured according to IASPEI standard for short-period Lg-wave magnitude mb(Lg)
AX_IN	Displacement amplitude of phase of type X (e.g., P, PP, S, etc.), measured on an instrument of type IN (wild card) (e.g., SP, short-period; LP, long-period; BB, broadband)
VX_IN	Velocity amplitude of phase of type X and instrument of type IN (wild card as above)
A	Unspecified displacement amplitude measurement
V	Unspecified velocity amplitude measurement
AML	Displacement amplitude measurement for nonstandard local magnitude
AMs	Displacement amplitude measurement for nonstandard surface-wave magnitude
Amb	Displacement amplitude measurement for nonstandard short-period body-wave magnitude
AmB	Displacement amplitude measurement for nonstandard medium to long-period body-wave magnitude
END	Time of visible end of record for duration magnitude

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