A MANUAL OF STANDARDIZED TERMINOLOGY, TECHNIQUES AND SCORING SYSTEM FOR SLEEP STAGES OF HUMAN SUBJECTS

Allan Rechtschaffen and Anthony Kales; Editors

U.S. Department of Health, Education, and Welfare
Public Health Service - National Institutes of Health
National Institute of Neurological Diseases and Blindness
Neurological Information Network
Bethesda, Maryland 20014

1968

Foreword

The Inaugural Meeting of the Association for the Psychophysiological Study of Sleep (APSS) was convened in 1960 for the purpose of adopting a standard scoring system for stages of sleep. The opportunity to discuss experimental results diverted these charter members from their original purpose and, instead, they decided to meet annually thereafter to communicate their latest research findings.

The need for a standard scoring system was reemphasized by Monroe's study (1967) which revealed serious unreliability in the scoring of certain sleep stages. Concern over this unreliability led to the inclusion of a special session on scoring at the Seventh Annual Meeting of APSS held that year. Subsequently, an ad hoc committee of investigators was formed under the auspices of the UCLA Brain Information Service to develop a terminology-scoring system that might be used universally by sleep researchers. The Committee members met on several separate occasions and corresponded extensively in the intervening periods. The Committee was composed of the following members, all of whom had considerable experience in scoring sleep records:

Ralph J. Berger, Ph.D., Department of Psychology, Crown College, University of California, Santa Cruz, California.

William C. Dement, M.D., Department of Psychiatry, Stanford University School of Medicine, Palo Alto, California.

Allan Jacobson, M.D., Department of Anatomy, University of California School of Medicine, Los Angeles, California.

Laverne C. Johnson, Ph.D., Navy Medical Neuropsychiatric Research Unit, U.S. Naval Hospital, San Diego, California.

Michel Jouvet, M.D., Laboratoire de Médecine Expérimentale, Faculté de Médecine, Lyon, France.

Anthony Kales, M.D., Department of Psychiatry, University of California School of Medicine, Los Angeles, California.

Lawrence J. Monroe, Ph.D., Department of Psychology, University of Illinois College of Medicine, Chicago, Illinois.

Ian Oswald, M.D., Department of Psychiatry, University of Edinburgh, Edinburgh, Scotland.

Allan Rechtschaffen, Ph.D., Departments of Psychiatry and Psychology, University of Chicago, Chicago, Illinois.

Howard P. Roffwarg, M.D., Albert Einstein Medical Center, Montéfiore Hospital, The Bronx, New York.

Bedrich Roth, M.D., Department of Neurology, Charles University Medical Faculty, Prague, Czechoslovakia.

Richard D. Walter, M.D., Division of Neurology, Department of Medicine, University of California School of Medicine, Los Angeles, California.

This proposal was prepared by the Committee with the expectation the standardization of recording techniques and scoring criteria would widely used and would markedly increase the comparability of result reported by different investigators. An evaluation of how much such standardization contributes to reliability of scoring will have to await the development of experience with the system and empirical testing.

Allan Rechtschaffen and
Anthony Kales, Co-Chairmen

TO PROVIDE CONTINUITY within the very extensive research on sleep stages which has been published in the last decade, it was the guiding principle of the Committee to retain, as much as possible, the terminology and criteria which have had the greatest use. Indeed, it is testimony to the accuracy and judgment of Dement and Kleitman (1957)* that their description of sleep stages has proven useful in a decade of voluminous research by hundreds of investigators without requiring major modification. In general, the present proposal represents a reaffirmation of their original criteria for the partition of sleep into stages, combined with the revisions and elaborations which must inevitably follow ten years of experience with their system.

Research utilizing the Dement-Kleitman criteria for scoring sleep stages has firmly established the fact, first noted by Loomis, Harvey and Hobart (1937), that sleep is not a steady state and that the sleep stages follow a fairly orderly cyclic pattern. While knowledge of the significance of each stage of sleep is incomplete, specific physiological and behavioral correlates of the various stages have been found. These and other correlates may eventually provide more meaningful descriptions of sleep than the stages described in the following section which emphasizes the EEG changes.

The terminology and scoring systems proposed here are not intended as restrictions upon the researcher who has substantive reasons for using different terms and criteria. However, it is strongly recommended that departures from these terms and criteria should be specified. Such specification would aid in comparing the results in different studies.

Although there is considerable comparability of sleep stage manifestations among various species, the differences are sufficiently great to require a separate scoring system for most species. This proposal is designed for adult humans. Even among human subjects, however, there are some individuals or groups whose polygraph recordings may require further description or elaboration than that provided by the stages proposed here. In such instances, the existence of established categories does not free the investigator from the task of devising a descriptive system which better communicates the unique features of the phenomena. For example, it is well known that human infants show combinations of polygraphic features which defy classification by the criteria proposed here. A strict adherence to the proposed system would not yield an adequate description of infant sleep.

These scoring criteria were further elaborated by W.C. Dement in a manual presented to the APSS meeting in 1962.

Terminology

EEG Terms

For the designation of specific EEG phenomena, the proposal of the Terminology Committee of the International Federation for Electroencephalography and Clinical Neurophysiology (Brazier, Cobb, Fischgold, Gastaut, Gloor, Hess, Jasper, Loeb, Magnus, Pampiglione, Remond, Storm van Leeuwen and Walter, 1961) is adopted except where specifically noted. Similarly, the Ten Twenty Electrode System of the International Federation (Jasper, 1958) is adopted for designation of electrode placements.

Stages

A more detailed discussion of scoring criteria will be presented later; for purposes of preliminary identification, the stages and their most prominent features are:

Stage W (wakefulness) - The EEG contains alpha activity and/or low voltage, mixed frequency activity.

Movement Time (MT) - Scoring epoch during which the polygraph record is obscured by movements of the subject.

Stage 1 - A relatively low voltage, mixed frequency EEG without rapid eye movements (REMs).

Stage 2 - 12-14 cycles per second (cps) sleep spindles and K complexes on a background of relatively low voltage, mixed frequency EEG activity.

Stage 3 - Moderate amounts of high amplitude, slow wave activity.

Stage 4 - Large amounts of high amplitude, slow wave activity.

Stage NREM (non-REM) - Stages 1, 2, 3, and 4 combined.

Stage REM - A relatively low voltage, mixed frequency EEG in conjunction with episodic REMs and low amplitude electromyogram (EMG).

It is recommended that the above stage designations be used instead of other terms. Some of the terms which have been previously used and which are no longer considered desirable are:

For Stage 1: descending Stage 1, sleep onset 1, pure 1, transitional sleep, drowsy sleep, low voltage-fast, Stage B.

For Stage 2: spindle sleep, Stage C, light sleep.

For Stage 3 and/or Stage 4: transitional sleep, delta sleep, slow sleep, slow wave sleep, light sleep, deep sleep, quiet sleep, orthosleep, telencephalic sleep, Stages D and E.

For Stage REM: paradoxical sleep, rhombencephalic sleep, Stage 1-REM, activated sleep, fast sleep, low voltage-fast sleep, deep sleep, light sleep, desynchronized sleep, D-state, archisleep, parasleep, emergent Stage 1, ascending Stage 1, Stage 5.

Although the physiological correlates of behavioral sleep remain a continuing research issue, generally, sleep has been polygraphically defined by Stages 1, 2, 3, 4, and REM. The same working definition is used here.

Techniques

As the quality and characteristics of a polygraph tracing depend upon the techniques used, the designation of criteria for scoring stages of sleep and wakefulness would be useless without some standardization of technique.

EEG Recording

A minimum paper speed of 10 mm/sec is recommended as the slowest which will permit clear visual resolution of alpha and sleep spindle frequency. Time constants shorter than 0.3 sec should not be used. Selective filtering below 20 cps should be reported. A minimal pen deflection of 7.5-10 mm for 50 microvolts (μV) is recommended; otherwise low amplitude sleep spindles may escape detection. Electrode resistances should not exceed 10K ohms at the beginning of the recording.

EEG patterns, and therefore the scoring of stages, may vary according to placement and derivation. Ideally, a standard array might include a large number of placements which would yield comprehensive regional information. However, regional differences are not critical for the scoring of sleep stages, except insofar as certain critical types of activity, i.e., alpha, vertex sharp waves, sleep spindles, K complexes, and delta waves are adequately registered. Further, the wide use of eight channel electroencephalographs and a desire to maximize data acquisition by running two subjects on each machine often limits the channels of information from each subject to four. For reasons to be elaborated in a later section, two eye movement channels and one EMG channel are considered minimal; EEG information would accordingly be limited to one channel. It is therefore necessary to specify the single optimal EEG derivation which can be confidently recommended for scoring sleep stages unless there are compelling reasons for doing otherwise.

When EEG information is limited to one derivation, the recommended derivation is C4/A1 or C3/A2 (Fig. 1). Either the right or left side may be used, since the EEG patterns from homologous areas are generally synchronous.

Sleep spindles, K complexes, and vertex sharp waves are clearly recorded from the C3 or C4 placements, and high voltage slow waves show maximal or nearly maximal amplitude if the referent maximizes interelectrode distance. Although alpha rhythm is better recorded from occipital areas, there is adequate registration at C3 or C4 to permit a precise evaluation of sleep onset according to EEG criteria.

The opposite ear or mastoid (A1, A2) is preferred over scalp referents because the ear or mastoid placement is also used as the recommended reference for electrodes that record eye movement potentials. In addition, use of the ear or mastoid reference maximizes interelectrode distance and avoids mixing activity from two different scalp areas.

The advantages of standardization are obvious. In the collective experience of the Committee, sleep stages may be adequately scored using EEG information obtained from the recommended derivation. If multiple channels of EEG information can be recorded, and special studies make additional derivations desirable, the results from the additional placements should be compared with the results from C3/A2 (or C4/A1) and substantial differences reported if they exist. There is no problem regarding interlaboratory comparability in scoring when multiple EEG channels are available, since C4/A1 (or C3/A2) will always be included in the array. However, when only one channel is recorded, presumed advantages of other placements must be carefully weighed against the obvious advantages of a standard EEG technique.

which maximizes comparability and replicability.* THE EEG CRITERIA FOR SCORING SLEEP STAGES SHOULD ALWAYS BE BASED ON TRACINGS OBTAINED FROM C4/A1 OR C3/A2. A schematic illustration of these electrode placements is given in Fig. 1.

Eye Movement Recording

To eliminate confusion between eye movement potentials and other signals which resemble them, at least two channels are necessary for recording eye movements. The recommended procedure is to record on one channel the potentials from an electrode approximately 1 cm above and slightly lateral to the outer canthus of one eye and a reference electrode on either the homolateral ear lobe or mastoid. On the second eye movement channel are recorded the potentials from an electrode 1 cm below and slightly lateral to the outer canthus of the other eye referred to the contralateral ear or mastoid, i.e., both eyes are referred to the same ear or mastoid electrode. This arrangement is shown in Fig. 1.

Because eye movements in Stage REM and wakefulness are binocularly synchronous, the suggested arrangement produces out-of-phase deflections on the two channels for almost all eye movements. Apparatus artifacts usually register as in-phase deflections or deflections on one channel only; artifacts from one of the outer canthus electrodes register as deflections on only one channel; artifacts from the referent electrode register as in-phase deflections on the two channels. Thus, the out-of-phase deflections produced by eye movements are easily distinguished from artifacts.

The above array for detecting eye movements has some disadvantages. Certain oblique eye movements can result in relatively flat tracings, as when a potential from the horizontal component of the eye movement is cancelled by an opposite potential from the vertical component. Also, convergent eye movements generate in-phase deflections with this arrangement. However, both of these situations are of minor importance because abundant out-of-phase deflections are usually present at the same time. Further, the above array does not permit any differentiation of horizontal and vertical eye

*Because the standard derivation is so important, it is advisable to prepare the subject with both C3 and C4 electrodes and A1 and A2 electrodes, even though only one pair of these may be recorded. This prior precaution would enable the investigator to change from one electrode pair to another in the event that artifact develops, and thus preserve a standard record. This "spare" could also be used as a reference electrode for EOG recordings. The use of only a single ear lobe or mastoid reference electrode is suggested in contrast to one clinical practice in which reference electrodes are joined in parallel.

movements. Such differentiation can be accomplished with the use of a supranasion reference, which produces in-phase deflections on the two recording channels for vertical eye movements. However, these vertical eye movements could be confused with artifacts. Also, the use of a supranasion reference could result in the introduction of considerable EEG signal in the eye movement tracings. These arrays with AC recordings do not yield precise information about the direction, size and speed of eye movements, e.g., large pen deflections could result from large horizontal eye movements or from a summation of the horizontally and vertically induced potentials in certain smaller oblique eye movements. The recommended array is intended to provide an economical arrangement to survey eye movements per se for the scoring of Stage REM. Measurements of the precise characteristics of those eye movements can only be accomplished with other techniques.

Where specific information about direction and size of eye movements is required, a four channel arrangement is suggested where electrodes horizontal to the outer canthi as well as infraorbital and supraorbital electrodes are each paired with the same ear or mastoid electrode and accorded a separate channel. Where specific information about eye position is required, DC recording must be introduced.

A minimum gain of 7.5 mm for 50 μV is recommended for eye movement recordings. Because the detection of slow eye movements is helpful in the analysis of a record, time constants faster than 0.3 sec should not be used.

EMG Recording

The recording of EMG from muscle areas on and beneath the chin (mental, submental) is strongly recommended because of its importance in the scoring of Stage REM which will be discussed later.

Because tonic EMG activity during sleep may be at a relatively low level, high gains should be used, preferably 20 μV/cm or higher. A minimum of high frequency filtering should be used, although at very high gains it is occasionally necessary to filter out AC artifacts. Time constants of

Stage W

Stage W corresponds to the waking state. It is characterized by alpha activity and/or a low voltage, mixed frequency EEG.

Certain subjects (alpha producers) may have a virtually continuous alpha record; other subjects may show little or no alpha activity in the waking record. This stage is usually, but not necessarily, accompanied by a relatively high tonic EMG, and often REMs and eye blinks are present in the EOG tracing.

Movement Time (MT), Body Movements, and Movement Arousal

The score "MT" is assigned to epochs which immediately precede or follow sleep stages, but in which the EEG and EOG tracings are obscured in more than half the epoch by muscle tension and/or amplifier blocking artifacts associated with movement of the subject. Where the EEG and EOG record can be seen in more than half the epoch in spite of the artifacts, the record is scored according to the prevailing EEG and EOG pattern. MT is not counted with either sleep or wake time but scored as a separate category unless the investigator specifies otherwise. Not enough is known about the behavioral correlates of MT to classify it unambiguously as either sleep or wakefulness. Where an epoch is obscured by muscle tension and/or amplifier blocking artifacts but is immediately preceded and followed by Stage W, the epoch is scored Stage W rather than MT.

MT should not be confused with the scoring of discrete body movements which may be of relatively short duration. Body movements can be detected by so many devices, and they can be defined in such a large variety of ways according to the investigator's interest, that it is left to each investigator to designate his own criteria (e.g., Rechtschaffen, Wolpert, Dement, Mitchell and Fisher, 1963). Body movements are not to be considered epoch scores in the same sense as MT. Body movements should be considered specific physiological events which can occur during MT or during stages.

Both MT and body movements are to be distinguished from movement arousals, which will assume some importance in the scoring of stages to be discussed later. A movement arousal will be defined as any increase in EMG on any channel, which is accompanied by a change in pattern on any additional channel. For EMG channels, the change in pattern may consist of either an increase in amplitude of the EMG signal or an amplifier blocking artifact. For EOG channels, the change of pattern may consist of either the occurrence of EMG activity, amplifier blocking artifacts, or blink artifacts. For EEG channels, the change of pattern may consist of either a decrease in amplitude, an increase in alpha activity, a paroxysmal burst of high voltage activity, the presence of EMG activity, or amplifier blocking artifacts. Movement arousals are not used as epoch scores, nor need they be tallied and reported. The major purpose in defining movement arousal is to aid in the scoring of stages by signalling the possibility of stage changes. For example, the interpretation of a short interval of relatively low voltage, mixed frequency EEG which follows Stage 2 will depend on whether the interval follows a movement arousal. Where there is a movement arousal, there is greater confidence that the subsequent interval represents a partial "arousal" to Stage 1 rather than a simple transient lapse of spindles.

In summary, a score of MT is used to account for epochs which are mostly obscured by movement artifacts. Body movements are not considered epoch scores; they are considered discrete physiological events which occur during epochs. The criteria for defining body movements are left entirely to the individual investigator. Movement arousal, which is explicitly defined in this proposal, is not used as an epoch score as is MT, nor is it intended primarily as a measure of body displacement as is body movement. Movement arousal is intended primarily as an aid in the scoring of stages inasmuch as an increase in muscle activity during sleep raises the possibility that the continuity of the prevailing sleep stage has been disturbed in some way.

Because MT involves more than half an epoch of movement artifact, and hence relatively large movements in most cases, the criteria for scoring MT will usually satisfy the criteria for body movements and

The term "relatively low voltage, mixed frequency EEG" is preferred over other terms previously used to describe the EEG pattern which is characteristic of Stage 1 and Stage REM. The term "Stage 1 EEG" is to be avoided, because the pattern also occurs in Stage REM and it would cause confusion to speak about "a Stage 1 EEG in Stage REM". The term "low voltage record" should not be used, because it does not accurately describe the EEG of Stage 1 or REM. According to the terminology of the International Federation, this term denotes a record with "no rhythmic activity above 10 μV, no activity above 20 μV". Many of the vertex sharp waves of Stage 1 and many of the saw-tooth waves of Stage REM exceed 20 μV.

movement arousals." Similarly, the criteria for body movements will usually satisfy the rather minimal requirements for movement arousal. However, the converse of these statements need not be true. Body movements may be of relatively short duration and fall far short of the criteria for MT. Movement arousal need indicate only some increase in muscle activity and does not necessarily involve the substantial spatial displacement of the body which is implied by body movement. Movement arousal could result from an isolated small muscle contraction, a vigorous blink, or a facial grimace.

Stage 1

Stage 1 is defined by a relatively low voltage, mixed frequency EEG with a prominence of activity in the 2-7 cps range.* The faster frequencies are mostly of lower voltage than the 2-7 cps activity. Stage 1 occurs most often in the transition from wakefulness to the other sleep stages or following body movements during sleep. During nocturnal sleep, Stage 1 tends to be relatively short, ranging from about 1 to 7 min. The highest voltage 2-7 cps activity (about 50-75 μV) tends to occur in irregularly spaced bursts mostly during the latter portions of the stage. Also during the latter portions of the stage, vertex sharp waves may appear, often in conjunction with the high amplitude 2-7 cps activity. The amplitude of the vertex sharp wave is occasionally as high as 200 μV. Scoring of Stage 1 requires an absolute absence of clearly defined K complexes and sleep spindles. Traces of low voltage activity at 12-14 cps may begin to appear as the transition to Stage 2 approaches, but this activity is not to be defined as sleep spindles until the rhythmic bursts are clearly visible for at least 0.5 sec, at which time they define the presence of Stage 2 (see below). Stage 1, especially following wakefulness, is characterized by the presence of slow eye movements, each of several seconds duration, which are usually most prominent during the

*The term "low voltage fast record" is rejected, not only because it is rejected by the International Federation, but also because the EEG of Stages 1 and REM contains a considerable amount of activity in the 2-7 cps band. The most popular term heretofore used to describe the EEG of Stages 1 and REM has been "low voltage, random". This term is now rejected because, according to the terminology of the International Federation, "random" means "recurring at inconstant time intervals", rather than denoting a mixture of frequencies.

rtions of the stage. Rapid eye movements are absent. Tonic EMG re usually below those of relaxed wakefulness.[1]

transition from a low voltage waking record to Stage 1 is characby a generalized slowing of the EEG. The transition from an alpha Stage 1 is characterized by a decrease in the amount, amplitude, ency of alpha activity. When the amount of record characterized activity combined with low voltage activity drops to less than 50% och and is replaced by relatively low voltage, mixed frequency the epoch is scored as Stage 1.

stage is defined by the presence of sleep spindles and/or K comd the absence of sufficient high amplitude, slow activity to define nce of Stages 3 and 4 (see below).

presence of a sleep spindle should not be defined unless it is of at sec duration, i.e., one should be able to count 6 or 7 distinct thin the half-second period.[2]

mplexes are defined as EEG wave forms having a well delineated sharp wave which is immediately followed by a positive component. duration of the complex should exceed 0.5 sec. Waves of 12-14 or may not constitute a part of the complex.[3] The K complex is maximal over vertex regions. K complexes can occur as a ressudden stimuli, but they also frequently occur in the absence of any e stimuli (Johnson and Karpam, 1968). Other polyphasic high

*ore detailed, differentiated description of EEG changes in the on from wakefulness to sleep, the reader is referred to Roth

the term "sleep spindles" has been widely used in sleep this term will be retained. The term should be used only ibe activity between 12 and 14 cps.

finition of K complex is at variance with the definition of. inology Committee of the International Federation which is as "Combination of vertex sharp waves and sigma paroxysm, spontaneously and especially in response to sudden stimuli leep."

tage slow waves occurring paroxysmally which do not have the precise rphology of the K complex are also frequently seen during Stage 2.

Because sleep spindles and K complexes are transient phenomena, atively long periods may intervene between these events without the urrence of a stage change. If less than 3 min of record which would imarily meet the requirements for Stage 1 intervene between sleep indles and/or K complexes, these intervening epochs are to be scored ge 2 if there is no indication of movement arousal or pronounced increase muscle tone during the interval in question.[4] If the interval without sleep indles or K complexes lasts 3 min or longer, the interval is scored as ge 1, even if it contains no movement arousal. If movement arousals or reases in muscle tone do occur during the interval in question, the por- of the record prior to them should be scored as Stage 2. The portion the record which follows should be scored as Stage 1 until the next sleep indle or K complex occurs, provided, of course, that the epoch requirements and criteria for Stage 1 are otherwise met.

ge 3

Stage 3 is defined by an EEG record in which at least 20% but not more than 50% of the epoch consists of waves of 2 cps or slower which have amplitudes greater than 75 μV from peak to peak (the difference between the most negative and positive points of the wave). The figures "20%" and "50%" fer specifically to the time occupied by the high amplitude, slow waves and not include intervals of higher frequency and lower amplitude activity tween these waves.[5] In actual scoring practice, it will be necessary to ake wave by wave measurements only for epochs with borderline amounts

he selection of a 3 min interval was arbitrary. It was based upon r judgment that inter-spindle intervals of that length might occur thout a stage change although such occasions would be rare.

n determining the percentage of an epoch which contains waves of .5 sec or slower and greater than 75 μV, a certain amount of unliability will be introduced because it is sometimes difficult to fine a wave by visual inspection. For example, it is not always. lear whether two contiguous potentials of the same polarity represent a single slow wave with a small wave of opposite polarity superimposed, or whether they represent two separate, faster waves. estimate the unreliability introduced by such ambiguities, three mbers of the Committee scored 28 selected epochs of 30 sec

high amplitude, slow wave activity, i.e., about 20% and 50%. For most pochs, judgments about Stages 3 and 4 can be made by comparison with the acings shown in Figs. 2-5. Figs. 2 and 4 present EEG tracings which are st below and just above the threshold for differentiating Stages 2 and 3. igs. 3 and 5 present EEG tracings which are just below and just above the reshold for differentiating Stages 3 and 4.

As noted in the original Dement-Kleitman criteria, an attempt should be made to distinguish between spontaneous K complexes and delta waves, although this distinction is not always easy. Sleep spindles may or may not be present in Stage 3.

Stage 4

Stage 4 is defined by an EEG record in which more than 50% of the epoch consists of waves of 2 cps or slower which have amplitudes greater than 75

Footnote continued from page 6

uration each for a percentage of the epoch which contained "acceptable" low waves. In the test sample used, these percentages ranged from about 35% to 80%; about two-thirds of the epochs fell in the narrower range between 40% and 60%, i.e., the range in which reliable differentiation of Stages 3 and 4 is most difficult. The rank order correlations between pairs of scorers on amount of high amplitude slow activity were .94, .94, and .91. Apparently, the ambiguities involved in the measurement of EEG waves are not so great or prevalent as to interfere with reliable scoring of the amount of an epoch which contains the specified low wave activity. The above reliability coefficients, however, should not be confused with the reliability of scoring Stages 3 and 4. In actual practice, a failure to score wave by wave in doubtful cases would result in lower reliabilities for stage scoring. On the other hand, actual records of continuous sleep may not be so heavily biased as the test samples with epochs of about 50% "acceptable" slow wave activity, and the reliability of scoring Stages 3 and 4 could be higher than the coefficients cited above, depending on the care and precision of the scorers.

There was considerable discussion in the Committee about the wisdom of applying an amplitude criterion in addition to a frequency criterion for the scoring of Stages 3 and 4. Amplitude is influenced by several variables apart from cerebral activity. These include: electrode differences, time constants, electrode placement, and interelectrode

μV peak to peak. Although only slightly more than half of an epoch may actually contain high amplitude, slow waves which meet the above specifications, most Stage 4 epochs have the appearance of being completely dominated by this activity. Intervals of lower amplitude, faster activity rarely persist for more than a few seconds in Stage 4, but are usually prominent in Stage 3 epochs.

Sleep spindles may or may not be present in Stage 4.*

Stage REM

Stage REM is defined by the concomitant appearance of relatively low voltage, mixed frequency EEG activity and episodic REMs. The EEG pattern resembles the one described for Stage 1, except that vertex sharp waves are not prominent in Stage REM. Also, in Stage REM distinctive "saw-tooth" waves (Berger, Olley and Oswald, 1962) frequently, but not always, appear in vertex and frontal regions in conjunction with bursts of REM. Alpha activity is usually somewhat more prominent during Stage REM than during Stage 1, and the frequency is generally 1-2 cps slower than during wakefulness (Johnson, Nute, Austin and Lubin, 1967). As with the EEG of Stage 1, there is an absolute absence of sleep spindles and K complexes.

Stage REM should not be scored in the presence of a relatively elevated tonic mental-submental EMG (Berger, 1961; Jacobson, Kales, Lehmann and Hoedemaker, 1964). The term "relatively elevated" requires explanation. At the high gains used for EMG recording during sleep, using surface electrodes it is difficult to define the absence of tonic EMG activity; even when the EMG tracing is of very low amplitude, there is almost always some residual fast activity which could represent either EMG activity or noise. Neither is it possible to define absolute EMG amplitude in a useful way, because amplitude varies considerably from subject to subject and with electrode position. However, for any given recording session with any given subject, tonic EMG will show considerable variation about which it is useful to make some relative statements. Specifically, during Stage REM the tonic mental-submental EMG tracing is not higher than the level during the preceding sleep stage. It almost always reaches its lowest levels during Stage REM. These low levels may or may not be reached during the other sleep stages, but they are reached during unambiguous REM periods. Therefore, a low amplitude EMG contributes little to the scoring of sleep stages, but the presence of a "relatively elevated" tonic EMG contributes to scoring information by precluding the scoring of Stage REM. There are infrequent occasions during Stage REM, especially in association with vigorous bursts of REMs, when the EMG tracing may show a slight transient increase in tonic activity or bursts of phasic activity for

Footnotes continued from page 7

distance. The variance introduced in the amount of Stages 3 and 4 by these factors will be minimized by standardization.

Other potential determinants of EEG amplitude such as skin resistance and individual differences in slow wave foci are difficult to evaluate. However, some implicit amplitude criteria are always involved in the visual discrimination of specific EEG activity. When the wave form is complex and highly characteristic, as in the sleep spindle, amplitude per se contributes little to the detection process, i.e., signal to noise ratio. In the case of slow wave activity where wave form is secondary, the major factor for easy detection, aside from frequency, is amplitude. Thus, for purposes of scoring and particularly for reliability of scoring, detection and rating of slow wave activity must require an explicit amplitude criterion. Therefore, the question of specifying the precise scoring parameters of Stages 3 and 4 is the major problem, and a number of factors entered into the decision of the Committee.

With regard to the amplitude criterion, there was no question that, although the results of measures of slow wave activity which stress the amplitude parameter and those which minimize it are highly correlated, there are some differences which made a choice more than academic.

The following summarizes the reasoning of the Committee's choice to utilize a relatively high amplitude criterion for delta activity in the scoring of Stages 3 and 4.

a) *Although some extra-cerebral determinants of amplitude stand as potential sources of variance in measures which emphasize amplitude, as abundant research has shown, this variance is not so great as to preclude relationships between such measures and other empirical variables.*

b) *A large majority of the Committee felt that the sleep EEG would not be adequately described by a scoring system which did not attend to the marked amplitude variations which are one of its most prominent features.*

c) *Most published EEG sleep research has utilized an amplitude criterion in the scoring of Stages 3 and 4; retention of such a criterion provides some continuity with this research.*

veral seconds. For purposes of stage scoring, these transient changes ıy be disregarded.

ıtures of Stage REM and sleep spindles

There are occasions, mostly during the first REM period of the night, en sleep spindles are interspersed with REMs and the EMG remains at Stage REM level throughout. The scoring in these situations is based on the following two principles.

1. Any section of record contiguous with Stage REM in which the EEG shows relatively low voltage, mixed frequency is scored Stage REM regardless of whether REMs are present, providing EMG is at the Stage REM level and there are no intervening movement arousals. (Situations which involve movement arousals will be discussed later.)
2. An interval of relatively low voltage, mixed frequency EEG record between two sleep spindles or K complexes is considered Stage 2 regardless of EMG level, if there are no REMs or movement arousals during the interval and if the interval is less than 3 min long. (This is simply a reiteration of the rules for scoring Stage 2.)

Examples of application of these rules are given below and illustrated ematically in Fig. 6. The letter designations of the illustrations correspond to the letter designations of the text.

A. A single sleep spindle* occurs in an epoch during which EMG is at the Stage REM level. The preceding and succeeding epochs are Stage REM and contain no sleep spindles. The epoch containing the sleep spindle is scored Stage REM because all of the epoch preceding and following the sleep spindle is considered Stage REM under rule #1 above.

B. In a 30 sec epoch, sleep spindles occur at the 10th and 20th seconds. The preceding and succeeding epochs were Stage REM. The first and last 10 sec of the epoch containing the sleep spindles are considered Stage REM under rule #1. The middle 10 sec is considered Stage 2 under rule #2. Because two-thirds (more than half) of the epoch is Stage REM, the epoch is scored as Stage REM (Fig. 6, illustration B_1). If, in the above situation, the sleep spindles had occurred at the 5th and 25th seconds, then two-thirds of the epoch would be considered Stage 2, and the epoch would be scored Stage 2 (Fig. 6, illustration B_2).

C. There are three successive epochs during which the EMG is at the Stage REM level; except for the sleep spindles to be noted below, the EEG is relatively low voltage, mixed frequency. REMs occur during the first 5 sec of the first epoch and during the last 5 sec of the third epoch. Sleep spindles occur at the 20th sec of the first epoch and during the 20th sec of the third epoch. There are no REMs or sleep spindles in the middle epoch.

   The first epoch is scored Stage REM because the first 20 sec of the epoch, i.e., until the sleep spindle, is considered Stage REM under rule #1.

   The middle epoch is scored Stage 2, even though it contains no sleep spindles, because under rule #2 all of the record between the two sleep spindles is considered Stage 2.

   The third epoch is scored Stage 2 because the first 20 sec of the epoch is considered Stage 2 under rule #2.

Start and End of Stage REM

The major problem in scoring Stage REM is the determination of the precise points at which REM periods begin and end. This problem arises primarily from the fact that three indicators, EEG, EOG, and EMG activity,

vertheless, it is recognized that measures of slow wave activity ich minimize amplitude might yield the same empirical relationships the measure chosen by the Committee. Also, it is possible that ternative measures of slow wave activity might have a usefulness and pirical significance not enjoyed by the measure chosen. Therefore, selection of the Committee should not deter investigators from ing measures of slow wave activity other than the one suggested here. wever, it is recommended that departures from the criteria specified re be reported in detail.

complexes can be substituted for sleep spindles in all of these lustrations.

which are used to define Stage REM may or may not change simultaneously. To aid in the determination of Stage REM onset and termination in instances where the three indicators do not change simultaneously, the following scoring problems are presented together with the scoring recommendations.

1. Start of Stage REM

Schematic illustrations of the rules for starting Stage REM are presented in Fig. 7. The letter designations of the illustrations correspond to the letter designations of the text below.

A. Sleep spindles and K complexes stop and the EEG changes to relatively low voltage, mixed frequency for one or more epochs before REMs start. Score all the record from the last sleep spindle or K complex as Stage REM if the EMG during the epochs before REMs is at the same level as after REMs and if there has been no intervening movement arousal. Score the record up to the last sleep spindle or K complex as Stage 2 irrespective of EMG level. In rare instances where there is a progression from Stage 3 or 4 to Stage REM, a parallel rule applies, except that slow wave activity is substituted for sleep spindles and K complexes.

B. Sleep spindles and K complexes stop and the EEG changes to relatively low voltage, mixed frequency for an interval of one or more epochs before REMs start; EMG remains at a relatively high level for some portion of this interval before it drops to the Stage REM level. Score Stage REM from the point where the EMG amplitude dropped, providing REMs occur before any additional sleep spindles or K complexes appear. The portion of the record following the last sleep spindle or K complex and prior to the EMG drop is considered as part of the preceding stage (usually Stage 2) unless it is 3 min or longer, in which case it is scored Stage 1.

C. Sleep spindles and K complexes stop and the EEG changes to relatively low voltage, mixed frequency for one or more epochs before REMs start; during these epochs there is a movement arousal. Score Stage REM at the point following the movement arousal at which the EMG tracing is reduced

to the Stage REM level providing there is no indication of a change to Stage 1 (see discussion under End of Stage REM, section C, page 11). If the interval between the cessation of sleep spindles and K complexes and the movement arousal is less than 3 min, it is scored Stage 2 (Fig. 7, illustration C_1). If the interval is 3 min or longer, it is scored Stage REM (Fig. 7, illustration C_2).

D. Sleep spindles and K complexes stop and the EEG changes to relatively low voltage, mixed frequency for an interval of one or more epochs before REMs start. During this interval, there is a movement arousal, and tonic EMG remains elevated for one or more epochs following the movement arousal before dropping to Stage REM level. Score Stage 1 for those epochs following the movement arousal during which EMG is relatively elevated. Score Stage REM when the EMG drops to the Stage REM level following the movement arousal. The epochs of relatively low voltage, mixed frequency EEG which precede the movement arousal are scored Stage 2 or Stage REM according to the 3 min rule cited under "C" (above).

2. End of Stage REM

Schematic illustrations of the rules for ending Stage REM are presented in Fig. 8. The letter designations of the illustrations correspond to the letter designations of the text below.

A. A period of relatively low voltage, mixed frequency EEG, but without eye movements follows contiguously from an unambiguous Stage REM. Score as Stage REM, regardless of duration, providing the EMG tracing remains at the Stage REM level and there are no intervening sleep spindles, K complexes, or movement arousals.

B. An interval of relatively low voltage, mixed frequency EEG, but without REMs, follows contiguously (no intervening sleep spindles, K complexes, or movement arousals) from an unambiguous State REM. Tonic EMG is initially at the Stage REM level but becomes elevated

later in the interval. Score Stage REM up to the point of EMG augmentation. Score Stage 1 from the point of EMG augmentation until there is some subsequent indication of a stage change, which is usually either a resumption of REMs (Fig. 8, illustration B_1) or the occurrence of sleep spindles and/or K complexes (Fig. 8, illustration B_2).

C. A special case frequently arises where a movement arousal interrupts the continuity of Stage REM, the mental-submental EMG quickly reverts to the Stage REM level following the movement arousal, the EEG remains relatively low voltage, mixed frequency, and there is a resumption of REMs or change to Stage 2 one or more epochs following the movement arousal. The problem is whether to score the interval following the movement arousal and the resumption of REMs or change to Stage 2 as Stage 1 or Stage REM. There is argument for Stage 1 inasmuch as a change to a relatively low voltage, mixed frequency pattern regularly follows many movement arousals which interrupt Stages 2, 3, and 4; there is no reason to assume that interruption of Stage REM would be immune to such changes to Stage 1. On the other hand, the general principle remains that a relatively low voltage, mixed frequency EEG contiguous with Stage REM is to be scored as Stage REM. Although the decision is difficult, there are differences between Stage 1 and Stage REM, apart from the presence or absence of REMs, which can be used to make a discrimination between the two. The Committee thought it best to list general guidelines for distinguishing between Stage 1 and Stage REM and leave it to the scorer to apply these guidelines judgmentally.

In general, the scoring of Stage 1 is favored in proportion to the size and duration of the movement arousal. This is based on the fact that, when movement arousals interrupt other stages, the duration of the post-movement Stage 1 is generally proportional to the magnitude of the movement.

A most important indication of Stage 1 is the presence of slow eye movements. Although slow eye movements are sometimes present during Stage

~~9. End of Stage REM~~

~~C. (Continued)~~

REM, they do not approach the abundance, magnitude, and pendular pattern of the slow eye movements during Stage 1. As long as there are prominent slow eye movements following the movement arousal, the investigator can feel confident about scoring Stage 1.

Although the EEG of Stage 1 and Stage REM are very similar, there are some differences which may be usefully noted. Stage 1 scoring is favored in proportion to the amount of alpha activity immediately following the movement arousal; this guide is in record with a general conception of the post-movement Stage 1 as a transition back to unambiguous sleep following a change in state which approached wakefulness. The presence of well formed vertex spikes favors the scoring of Stage 1, whereas the appearance of well formed saw-tooth waves indicates Stage REM.

Incipient signs of sleep spindles and K complexes may also be useful in making the difficult discrimination between Stage 1 and Stage REM following movement arousals. The point here is best indicated by considering the typical transition from Stage 1 to Stage 2 at the beginning of sleep. Just before well formed sleep spindles and K complexes appear in the record, one can usually detect incipient signs of this activity. For example, there may be traces of very low voltage 12-14 cps activity scattered in the record which do not persist for the full half second required to meet the definition of a sleep spindle; there may be wave forms which begin to approach the morphology of the K complex, but do not fulfill the requirement. When such "incipient" sleep spindles and K complexes appear in a relatively low voltage, mixed frequency record which follows a Stage REM interrupting movement arousal, they may be taken as supporting evidence that the interval between the arousal and the incipient sign has been Stage 1.

Publication Style

If an abbreviation for REM is used in a language other than English, it is recommended that REM be added at the end in parentheses. For discursive portions of the text, the term "REM sleep" may be used instead of Stage REM and the term "NREM sleep" may be used instead of Stage NREM. Stage REM periods may be designated simply as REM periods. The abbreviation "REM", in and of itself, should be taken to mean "rapid eye movement". For example, "The subject had 100 minutes of Stage REM, four REM periods with an average of eight REMs per minute."

Some uniformity is needed in the abbreviations used to indicate quantities of sleep recording. It is suggested that the letter "T" at the beginning of an abbreviation always represent "total" and that percentage always be represented by the sign "%" at the beginning of an abbreviation. The letter "S" in the second position should always designate "Stage," and the third letter or number should indicate the specific stage in question. According to this system, quantities of sleep stages are given in the form indicated by the examples given below:

TSR - Total Stage REM
%SR - Percentage Stage REM
TSN - Total Stage NREM
%SN - Percentage Stage NREM
TS1 - Total Stage 1
%S1 - Percentage Stage 1
TS2 - Total Stage 2
%S2 - Percentage Stage 2

Where percentages or fractions are used, it is important to indicate clearly the specific numerator and denominator.

For the designation of psychophysiological measures, the term nomenclature and abbreviations of the journal Psychophysiology are recommended.

The above listing of abbreviations should not be interpreted as necessarily indicating that abbreviations are encouraged, but simply suggests a standardization of abbreviations in those instances where they are used.

Just as there is saving in "decoding" time when the same abbreviations are used in different articles, so there is some case of visual recognition to be gained by using a common format for the most frequent kinds of graphic presentation. It is suggested that in histograms, white represent wakefulness, diagonal lines represent sleep, cross-hatching represent Stage NREM, and black represent Stage REM. Where it is desirable to represent the individual NREM stages separately, it is left to the investigator's ingenuity to design different cross-hatchings or stipling effects for each stage.

Where stages are represented by different ordinal levels, as in figures which show the sequence of sleep stages with time (which is demarcated on the abscissa), the stages should be accorded the following ordinal positions (listed from top to bottom): W, REM, 1, 2, 3, 4. The practice of assigning Stage 1 and Stage REM to the same ordinal level is not recommended because it increases the possibility of confusion between the two stages. Vertical marks may be used to designate movements. This ordinal arrangement of stages was selected because it is convenient, not because it has any additional significance, such as a representation of sleep depth. It is now well known that sleep stages cannot be graded unambiguously on a generalized depth of sleep dimension (e.g., Rechtschaffen, Hauri and Zeitlin, 1966).

When the polygraph tracings themselves are presented, it is suggested that tracings be arranged from top to bottom in the following order: eye movements, EMG, EEG, and other polygraphic tracings such as ECG and respiration.

Concluding Comments

This manual for a standard terminology and scoring system reflects the consensus of a group of investigators each having many years of experience in the scoring of polygraphic sleep records. Initial discussion revealed a number of issues that needed to be resolved. The development of the manual required extensive discussion, correspondence and revision until each of these issues was resolved to the satisfaction of the entire Committee. This handbook should be viewed as a working instrument rather than a statute. Many of the decisions made are based upon an underlying conception of the organization of sleep stages which future research may prove wrong. Experience with the manual may suggest possible revisions. When these suggestions accumulate appreciably, it would seem in order to have a review of the manual.

Bibliography

Berger, R. J. Tonus of extrinsic laryngeal muscles during sleep and dreaming. Science, 134: 840, 1961.

Berger, R.J., Olley, P. and Oswald, I. The EEG, eye movements and dreams of the blind. Quart. J. Exp. Psychol., 14: 183-186, 1962.

Brazier, M.A.B., Cobb, W.A., Fischgold, H., Gastaut, H., Gloor, P., Hess, R., Jasper, H., Loeb, C., Magnus, O., Pampiglione, G., Remond, A., Storm van Leeuwen, W. and Walter, W.G. Preliminary proposal for an EEG terminology by the Terminology Committee of the International Federation for Electroencephalogra; and Clinical Neurophysiology. Electroenceph. clin. Neurophysiol. 13: 646-650, 1961.

Brown, C.C. A proposed standard nomenclature for psychophysiologic measures. Psychophysiol., 4: 260-264, 1967.

Dement, W., and Kleitman, N. Cyclic variations in EEG during sleep and their relation to eye movements, body motility, and dreaming. Electroenceph. clin. Neurophysiol., 9: 673-690, 1957.

Jacobson, A., Kales, A., Lehmann, D., and Hoedemaker, F.S. Muscle tonus in human subjects during sleep and dreaming. Exp. Neurol., 10: 418-424, 1964.

Jasper, H.H. (Committee Chairman). The ten twenty electrode system of the International Federation. Electroenceph. clin. Neurophysiol., 10: 371-375, 1958.

Johnson, L.C. and Karpam, W.E. Autonomic correlates of the spontaneous K-complex. Psychophysiol., 4: 386, 1968. (Abstract. Article in pre

Johnson, L.C., Nute, C., Austin, M.T. and Lubin, A. Spectral analysis of the EEG during waking and sleeping. Electroenceph. clin. Neurophysiol., 23: 80, 1967.

Loomis, A.L., Harvey, E.N., and Hobart, G.A. Cerebral states during sleep as studied by human brain potentials. J. Exp. Psychol., 21: 127-144, 1937.

Monroe, L.J. Inter-rater reliability of scoring EEG sleep records. Paper read at the Association for Psychophysiological Study of Sleep Meeting, Santa Monica, California, April, 1967. Abstract in Psychophysiol., 4: 370-371, 1968.

Rechtschaffen, A. Personal communication, 1968.

Rechtschaffen, A., Hauri, P., and Zeitlin, M. Auditory awakening thresholds in REM and NREM sleep stages. Percept. Motor Skills, 22: 927-942, 1966.

Rechtschaffen, A., Wolpert, E.A., Dement, W.C., Mitchell, S.A., and Fisher, C. Nocturnal sleep of narcoleptics. Electroenceph. clin. Neurophysiol., 15: 599-609, 1963.

Roth, B. The clinical and theoretical importance of EEG rhythms corresponding to states of lowered vigilance. Electroenceph. clin. Neurophysiol., 13: 395-399, 1961.

ILLUSTRATIONS

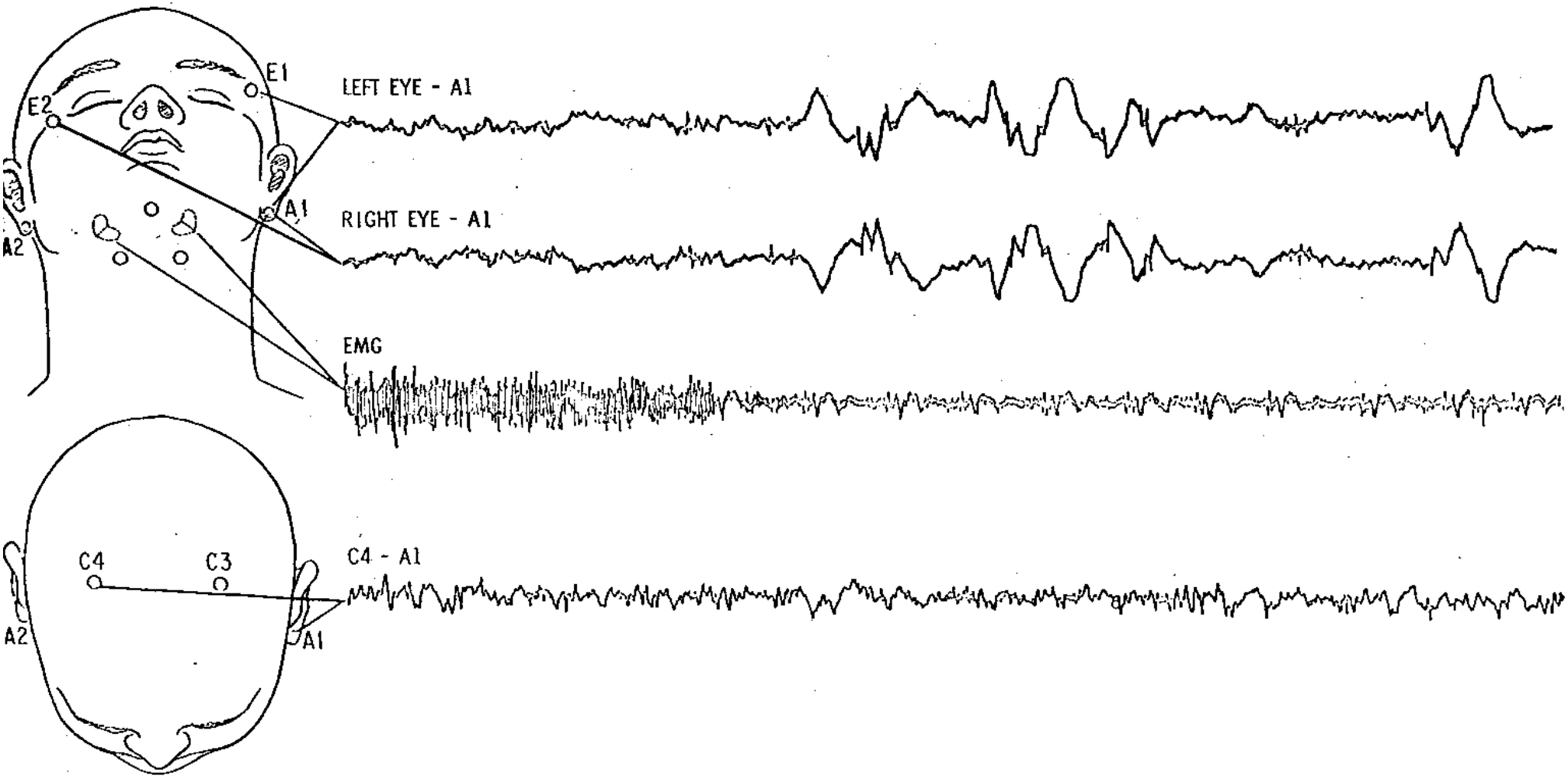


FIGURE 1

Upper drawing illustrates the placement of E1, E2, A1, and A2 electrodes for detection of eye movements and also shows two methods for recording tonic EMG from mental and submental muscle areas. Lower drawing illustrates the placement of C3, C4, A1, and A2 electrodes for EEG recording of sleep stages. (See text, pages 2-4). This epoch illustrates the onset of Stage REM. Note relatively low voltage mixed frequency EEG, REMs and sharp decrease in the tonic EMG.

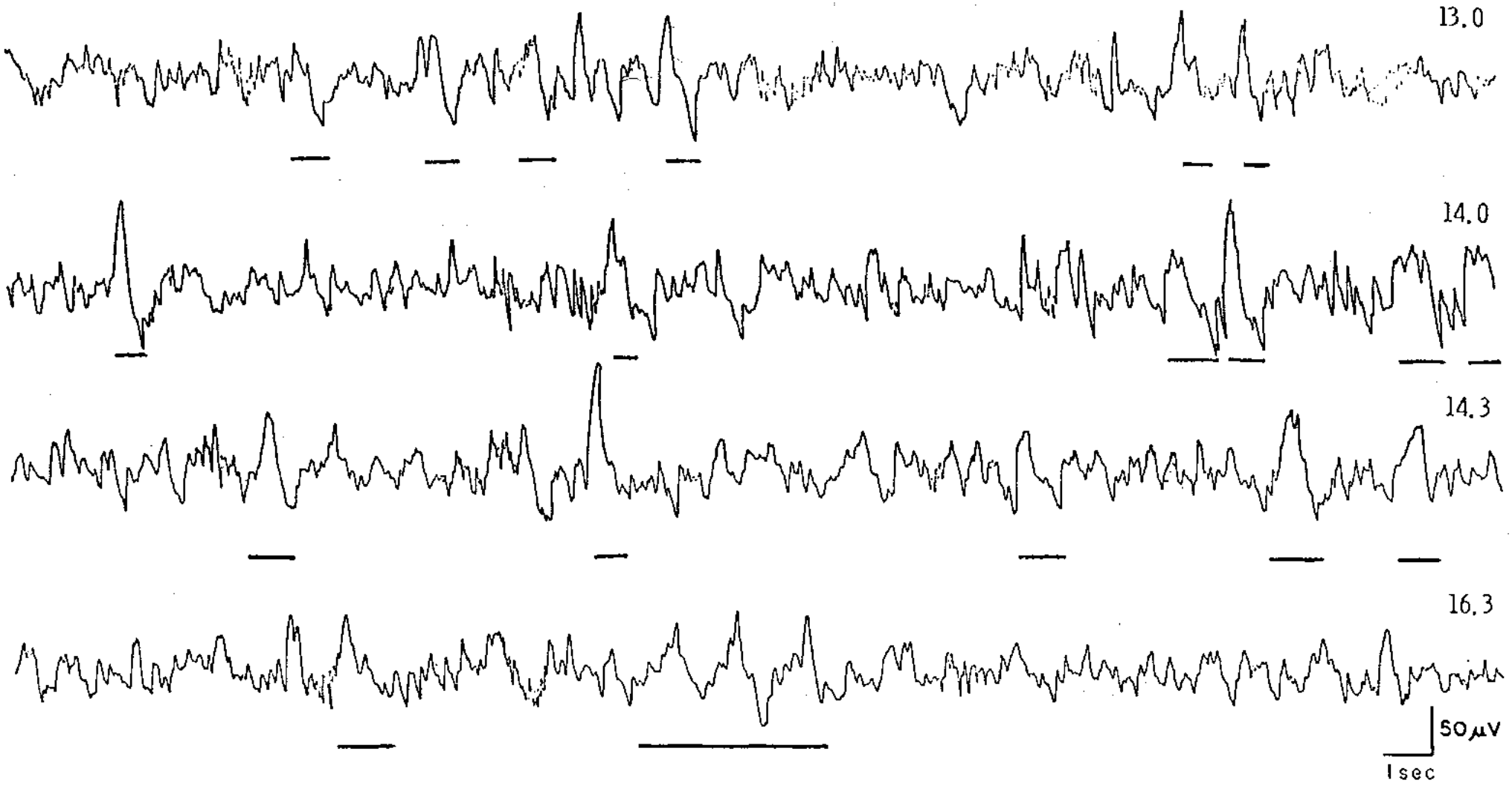


FIGURE 2

Comparison of EEG tracings (C3, A2 derivations) in Stages 2 and 3. Tracings from different portions of a sleep record were selected as an aid in the discrimination of the two stages. The four tracings on this page are Stage 2. They were deliberately selected because the percentage of high amplitude, slow wave activity was almost, but not quite enough, to qualify as Stage 3. The percentage of acceptable, high amplitude, slow wave activity in each tracing is listed on the right hand side of the recordings.

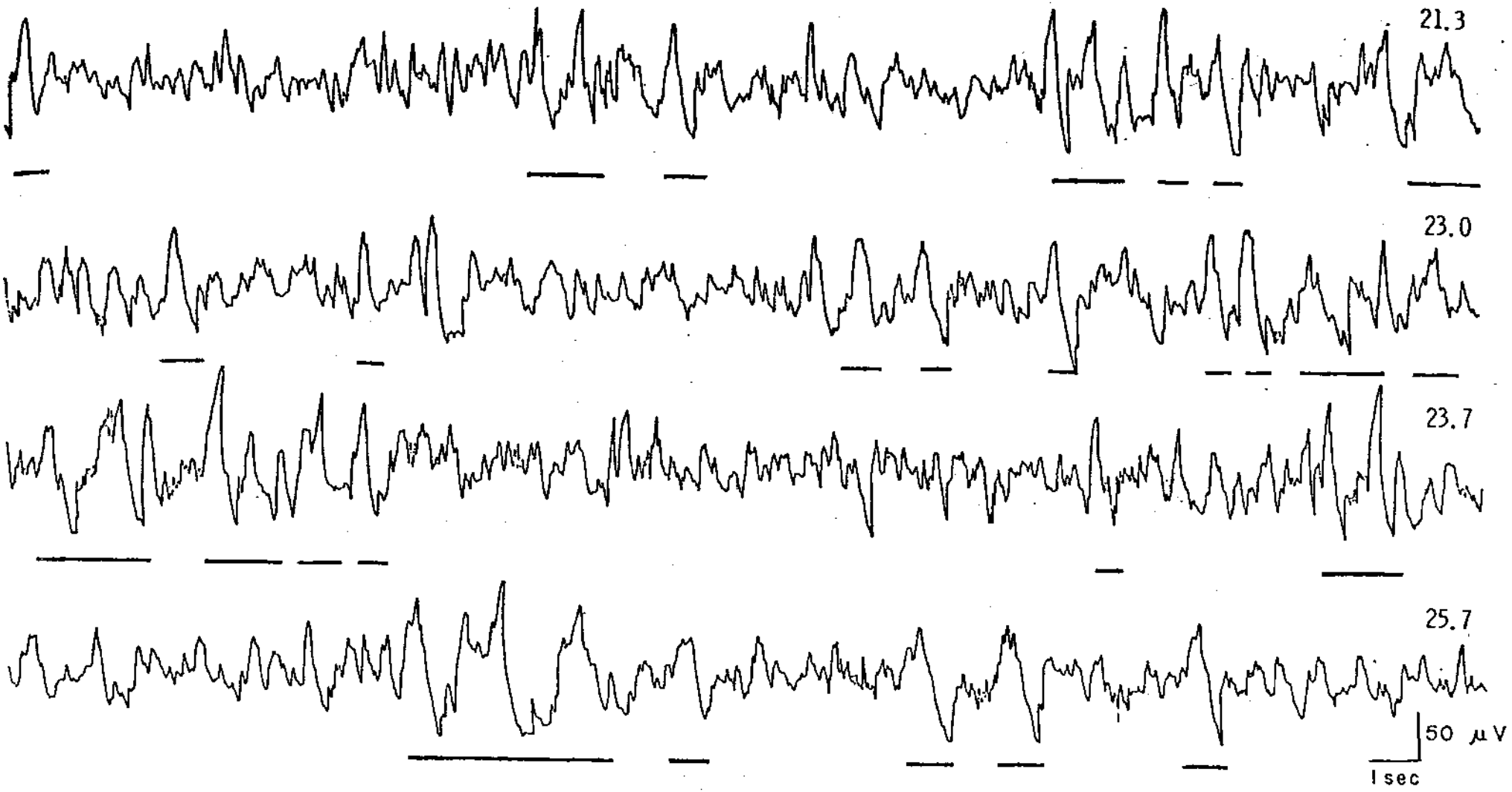


FIGURE 2 (Continued)

The four tracings on this page were selected because they show just enough high amplitude, slow wave activity to qualify for Stage 3. In borderline instances where there is a question of whether to score Stage 2 or Stage 3, a comparison of the record in question with these tracings may facilitate a decision. The underlined portions of each tracing were considered "acceptable" high amplitude, slow wave activity, i.e., 2 cps or slower and greater than 75 µV peak to peak. These illustrations depict 30 sec epochs recorded on a Beckman Type R Dynograph with a paper speed of 10 mm/sec, a time constant of 0.3 sec and a calibration of 50 µV/cm. (For Figs. 2-5, see text, pages 6-7.)

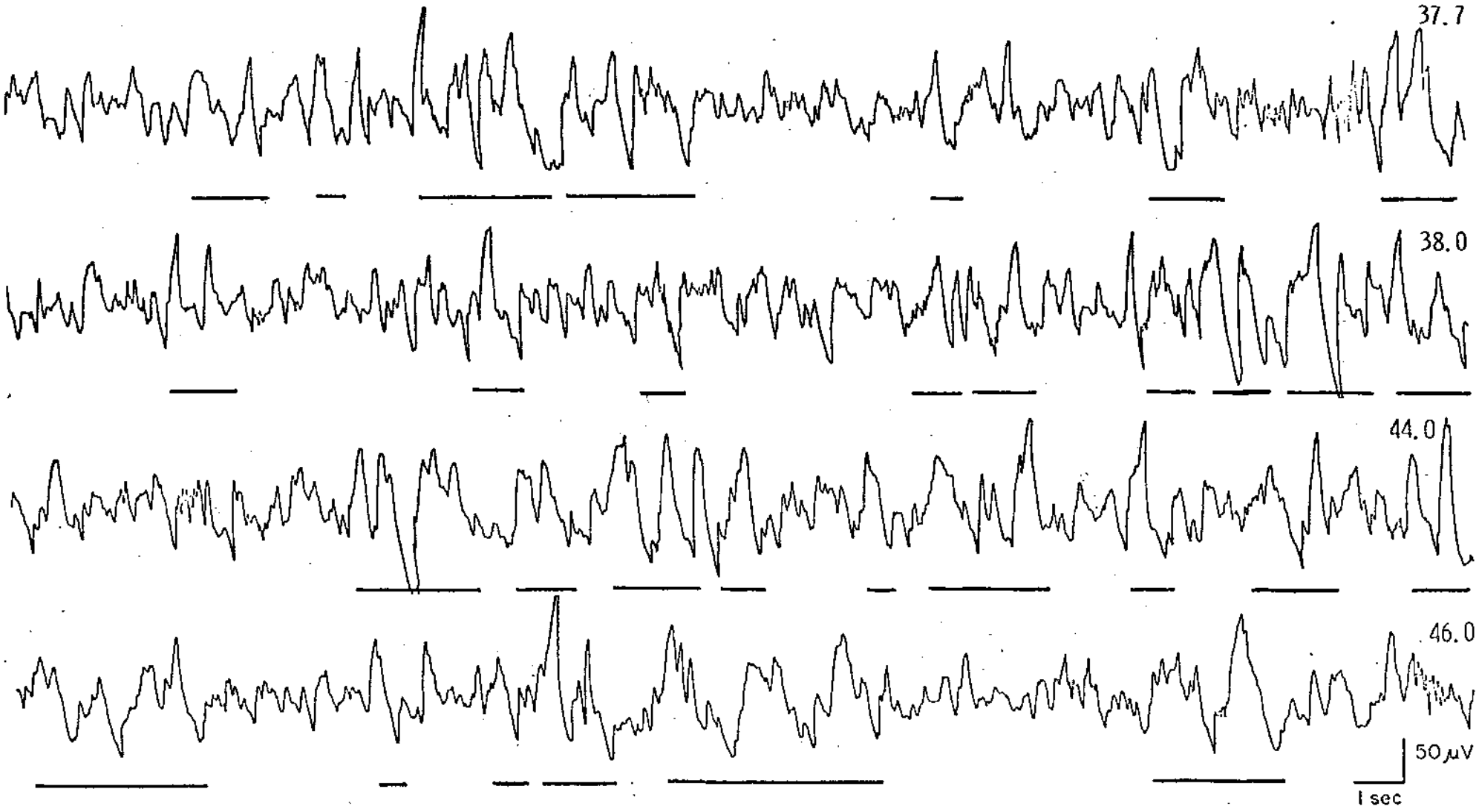


FIGURE 3

Comparison of EEG tracings (C3, A2 derivations) in Stages 3 and 4. Tracings from different portions of a sleep record were selected as an aid in the discrimination of the two stages. The four tracings on this page are Stage 3. They were deliberately selected because the amount of high amplitude, slow wave activity was almost, but not quite enough, to qualify as Stage 4.

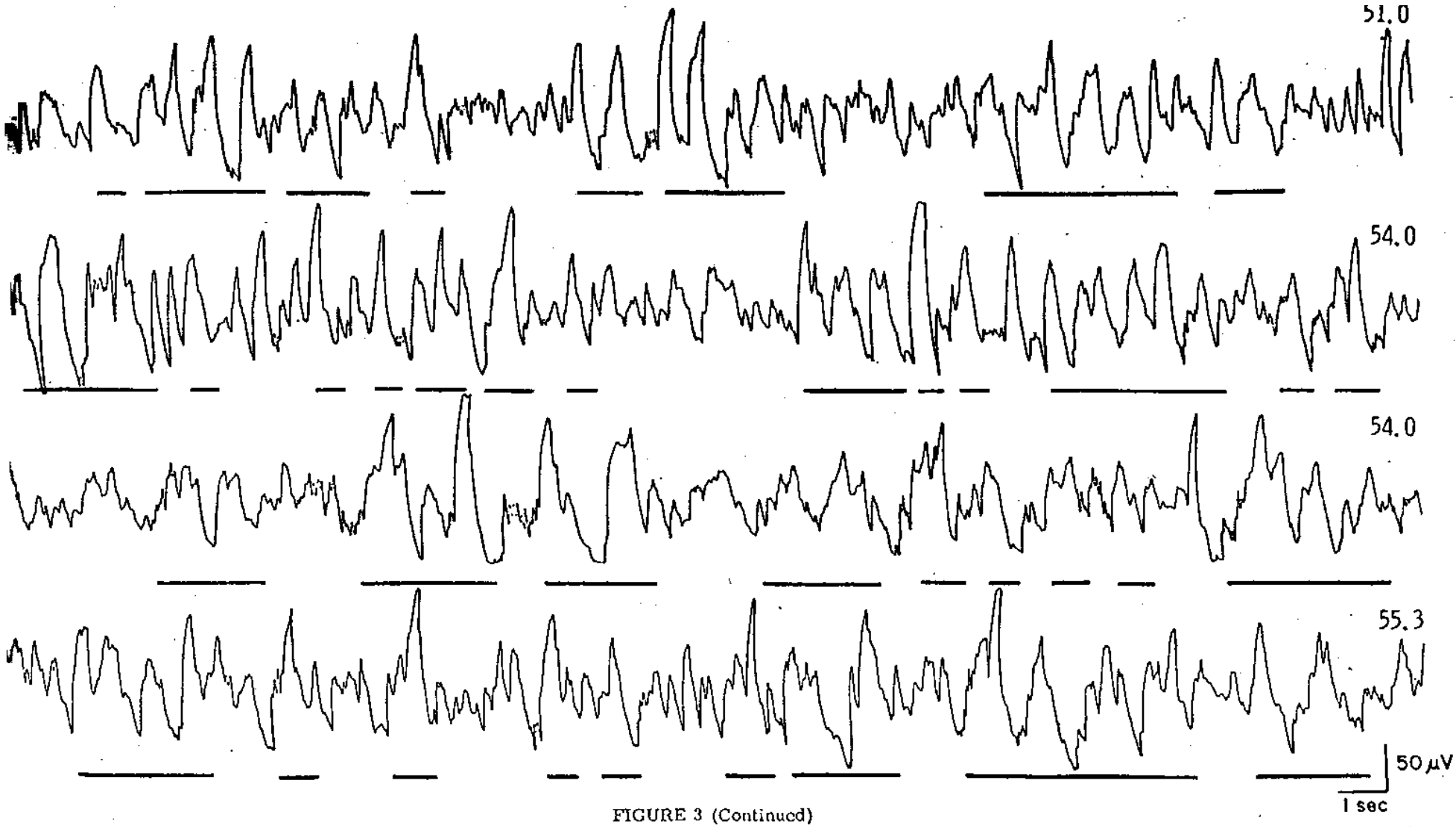


FIGURE 3 (Continued)

The four tracings on this page were selected because they show just enough high amplitude slow wave activity to qualify for Stage 4. In borderline instances where there is a question of whether to score Stage 3 or Stage 4, comparison of the record in question with these tracings may facilitate decision. The underlined portions of each tracing were considered "acceptable" high amplitude, slow wave activity, i.e., 2 cps or slower and greater than 75 μV peak to peak. These illustrations depict 30 sec epochs recorded on a Beckman Type R Dynograph with a paper speed of 10 mm/sec, a time constant of 0.3 sec and a calibration of 50 μV/cm.

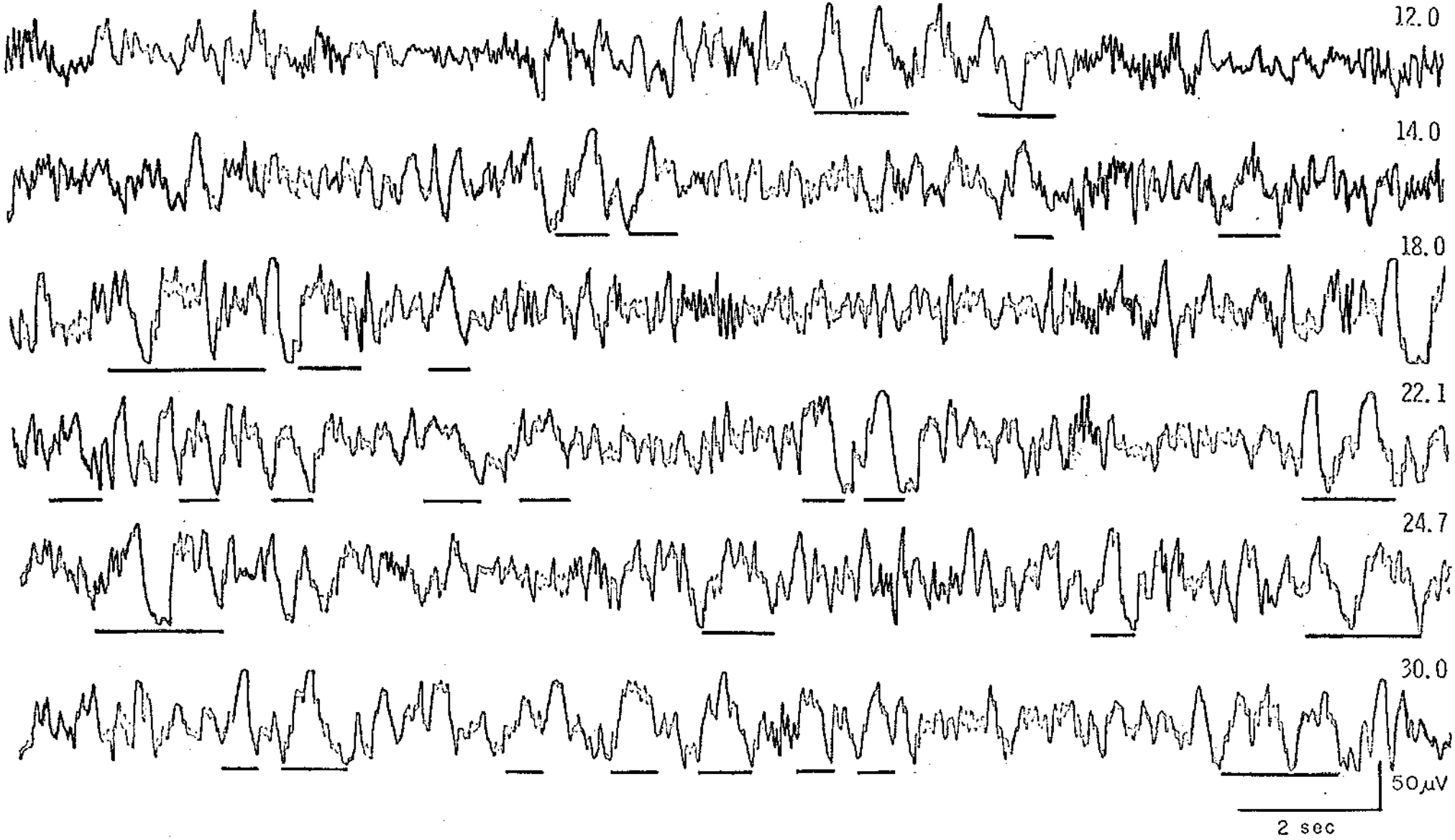


FIGURE 4

The top three tracings are Stage 2 and contain increasing percentages of high amplitude, slow wave activity but not enough to qualify for Stage 3. The bottom three tracings contain increasing percentages of high amplitude, slow wave activity and qualify as Stage 3. The tracings depict 20 sec epochs recorded on a Grass Model IV-C electroencephalograph with a paper speed of 15 mm/sec, a time constant of 0.3 sec and a calibration of 50 μV/cm.

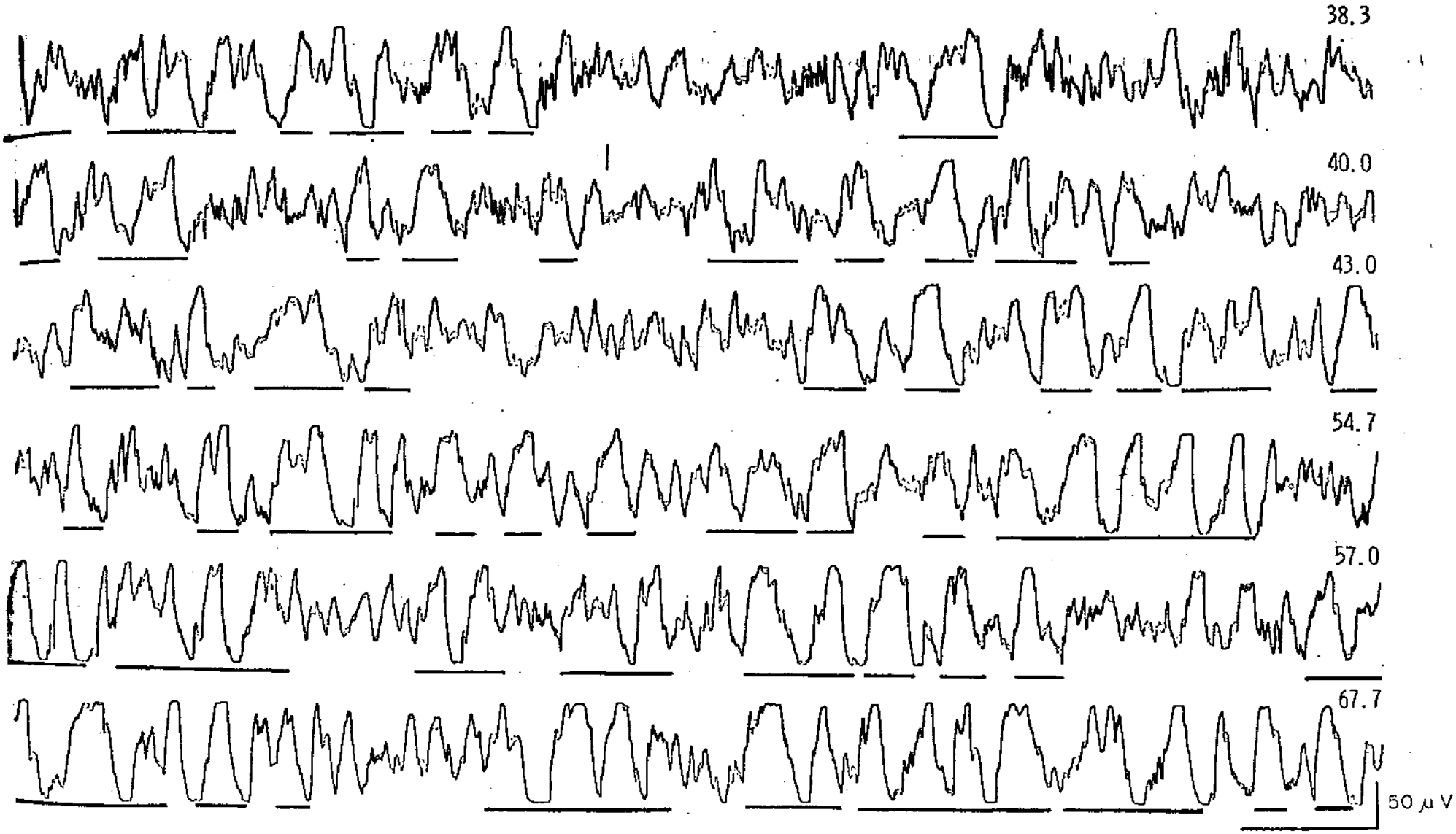


FIGURE 5

The top three tracings are Stage 3 and contain increasing percentages of high amplitude, slow wave activity, but not enough to qualify for Stage 4. The bottom three tracings contain increasing percentages of high amplitude, slow wave activity and qualify as Stage 4. The tracings depict 20 sec epochs recorded on a Grass Model IV-C electroencephalograph with a paper speed of 15 mm/sec, a time constant of 0.3 sec and a calibration of 50 μV/cm.

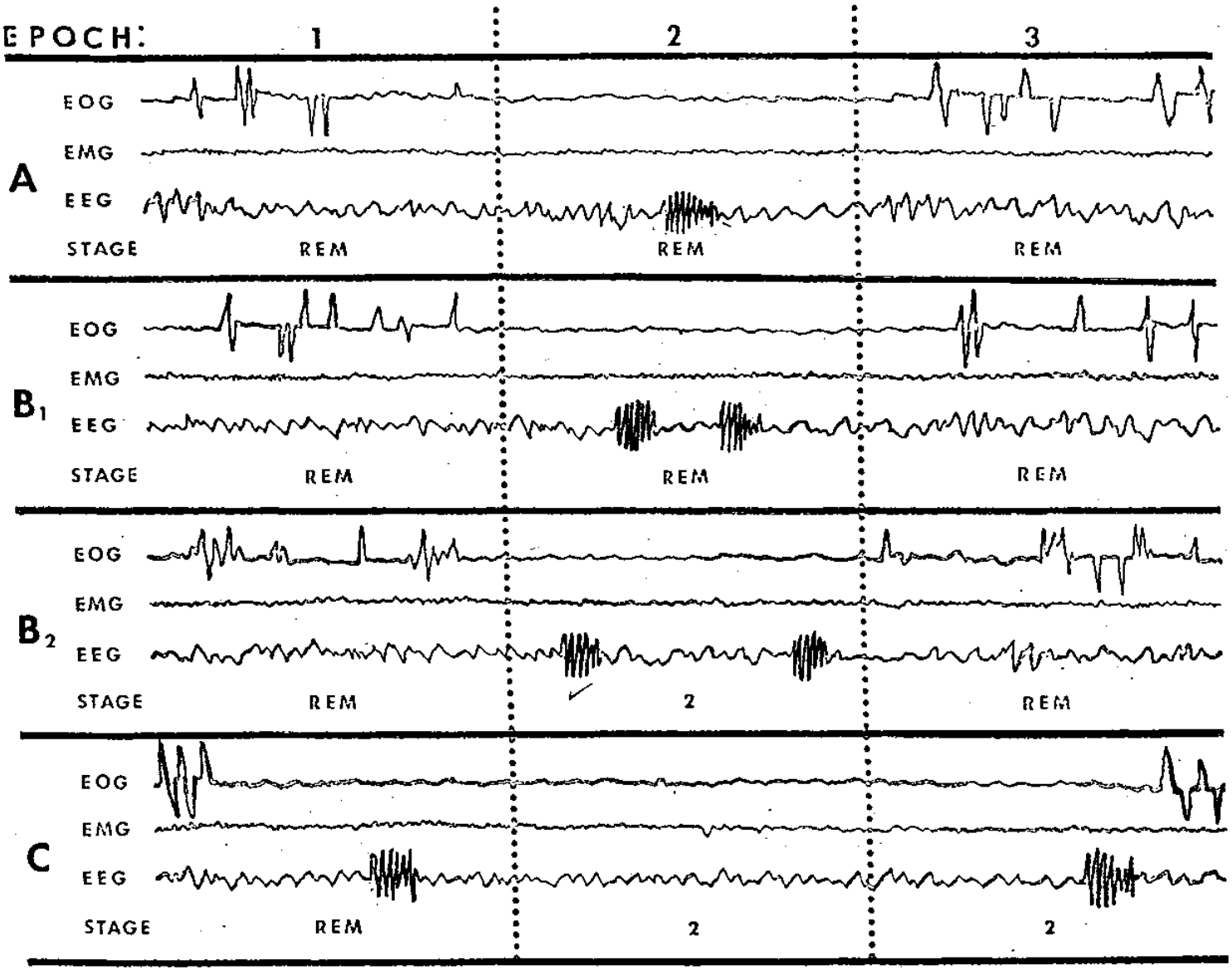

EPOCH:
1
2
3
A
EOG
EMG
EEG
STAGE
REM
REM
REM
B1
EOG
EMG
EEG
STAGE
REM
REM
REM
B2
EOG
EMG
EEG
STAGE
REM
2
REM
C
EOG
EMG
EEG
STAGE
REM
2
2

FIGURE 6

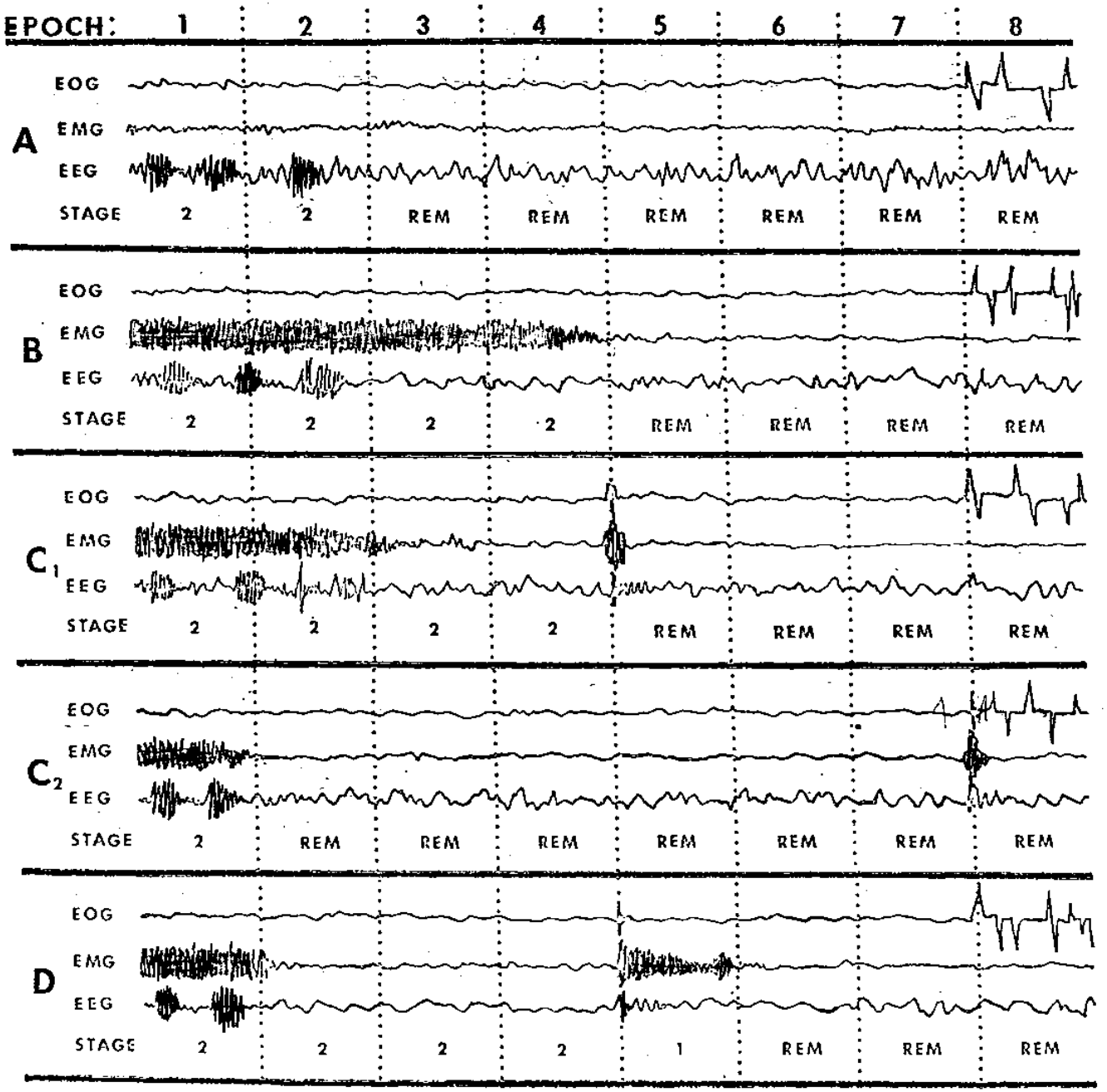


FIGURE 7

Schematic illustrations of rules for scoring the start of Stage REM. See text, page 9, for explanation.

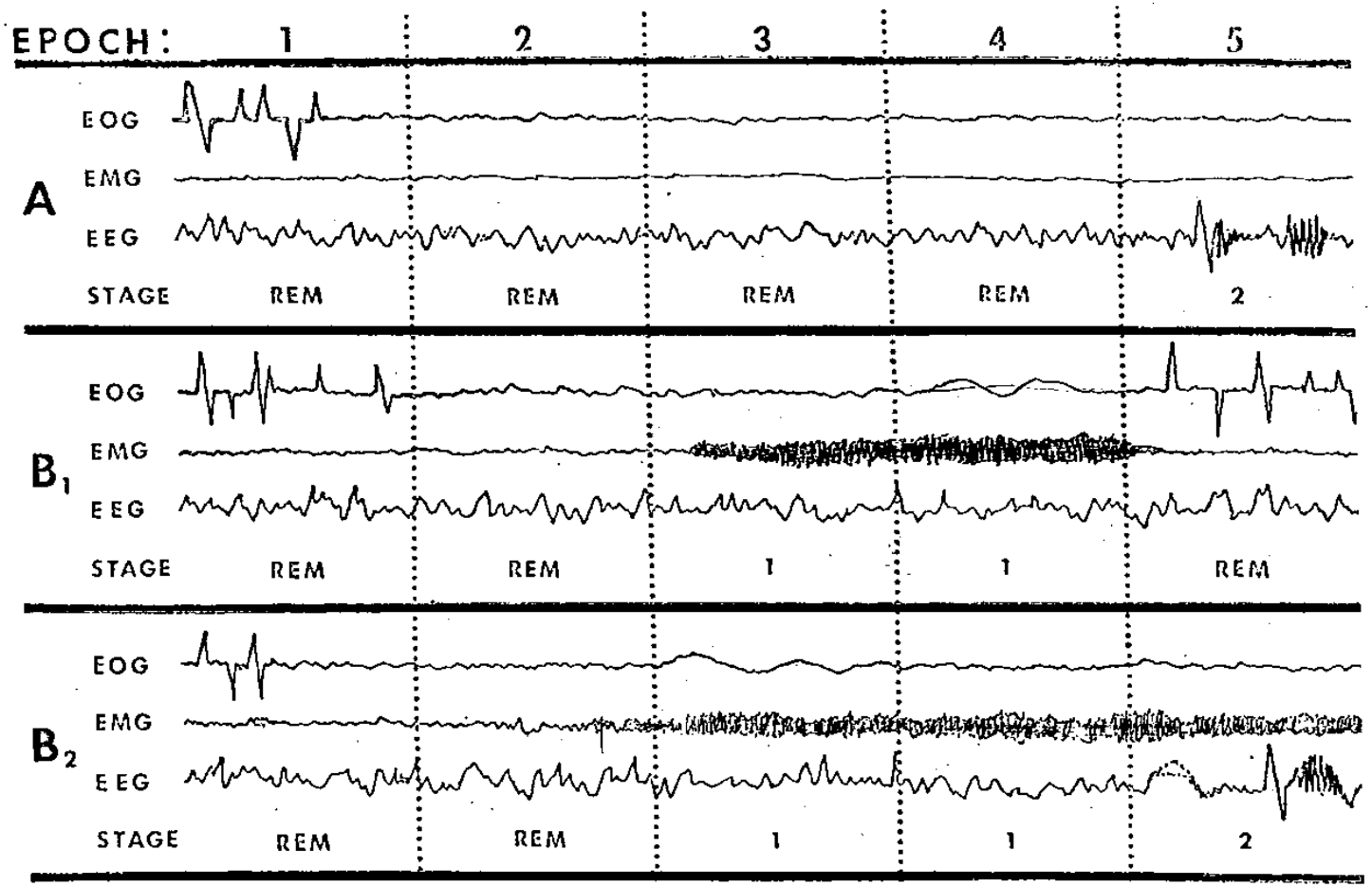
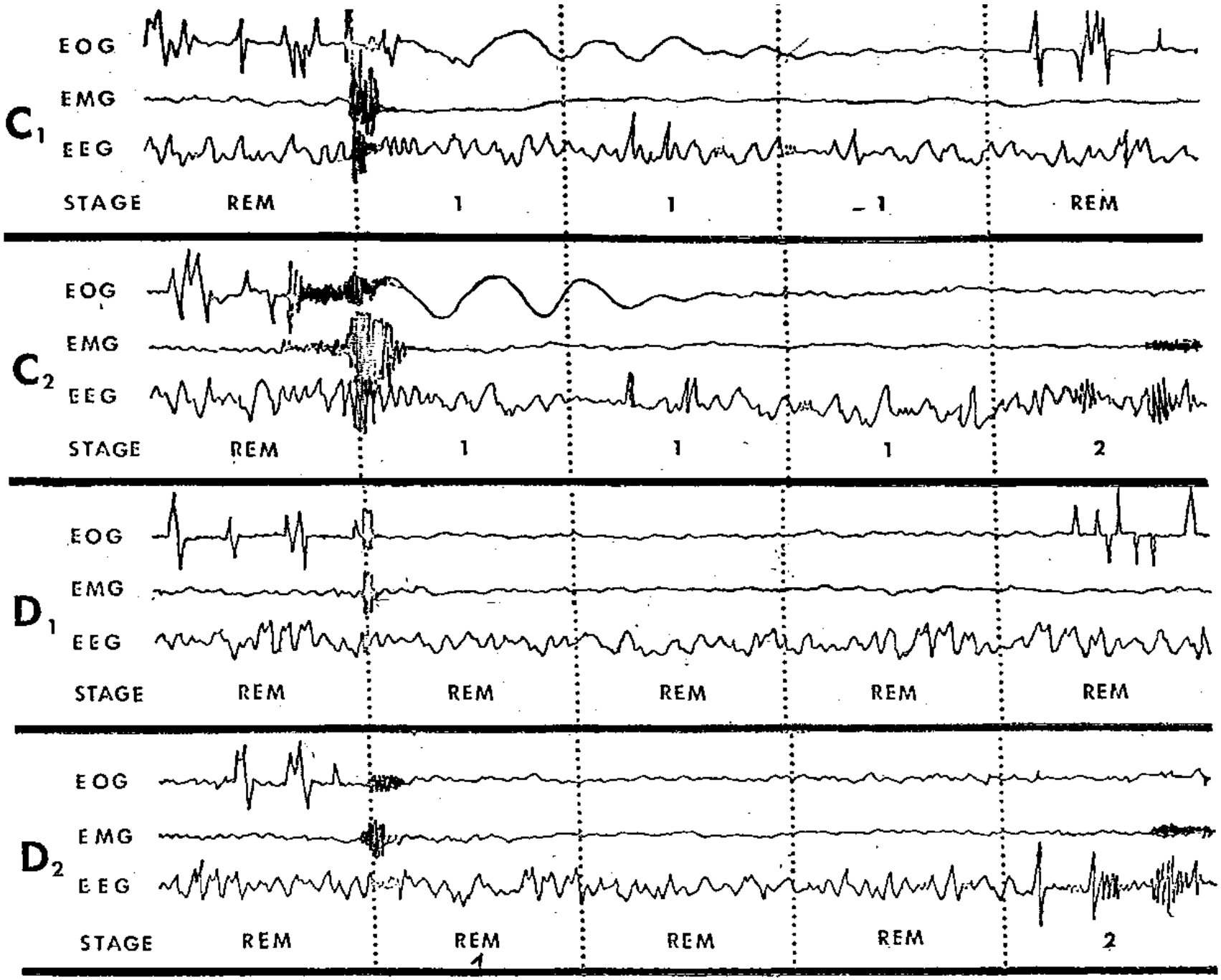

EPOCH: 1 2 3 4 5
A
EOG
EMG
EEG
STAGE REM REM REM REM 2
B1
EOG
EMG
EEG
STAGE REM REM 1 1 REM
B2
EOG
EMG
EEG
STAGE REM REM 1 1 2

FIGURE 8


C1
EOG
EMG
EEG
STAGE REM 1 1 _1 REM
C2
EOG
EMG
EEG
STAGE REM 1 1 1 2
D1
EOG
EMG
EEG
STAGE REM REM REM REM REM
D2
EOG
EMG
EEG
STAGE REM REM REM REM 2

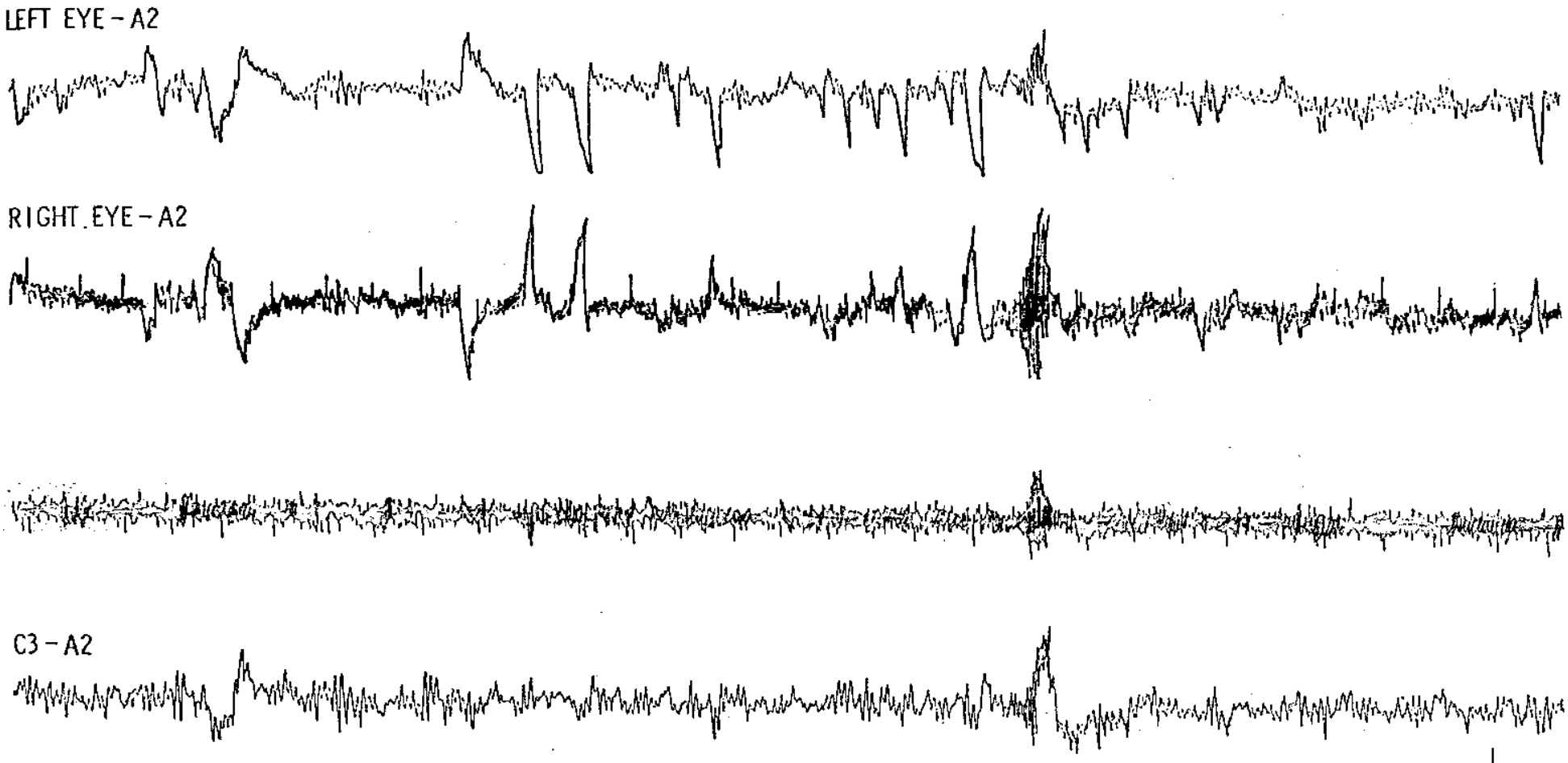


FIGURE 9

Stage W. This epoch illustrates an unambiguous Stage W. Note the relatively continuous alpha activity and the REMs.

FIGURES 9-22

Epochs from the various stages of subject 1 are presented. The subject was a 19 year old, normal, male college student. All the tracings are from the same night and were recorded on a Beckman Type R Dynograph. Each tracing represents a 30 sec epoch recorded at a paper speed of 10 mm/sec. For the eye movement and EEG channels calibration was 50 μV/cm. Time constant was 0.3 sec. For the EMG channel, the time constant was 0.03 sec. In Figs. 9-13, the calibration for the EMG channel was only 50 μV/cm in order to minimize ink splattering. In Figs. 14-22, the EMG calibration was 10 μV/cm.

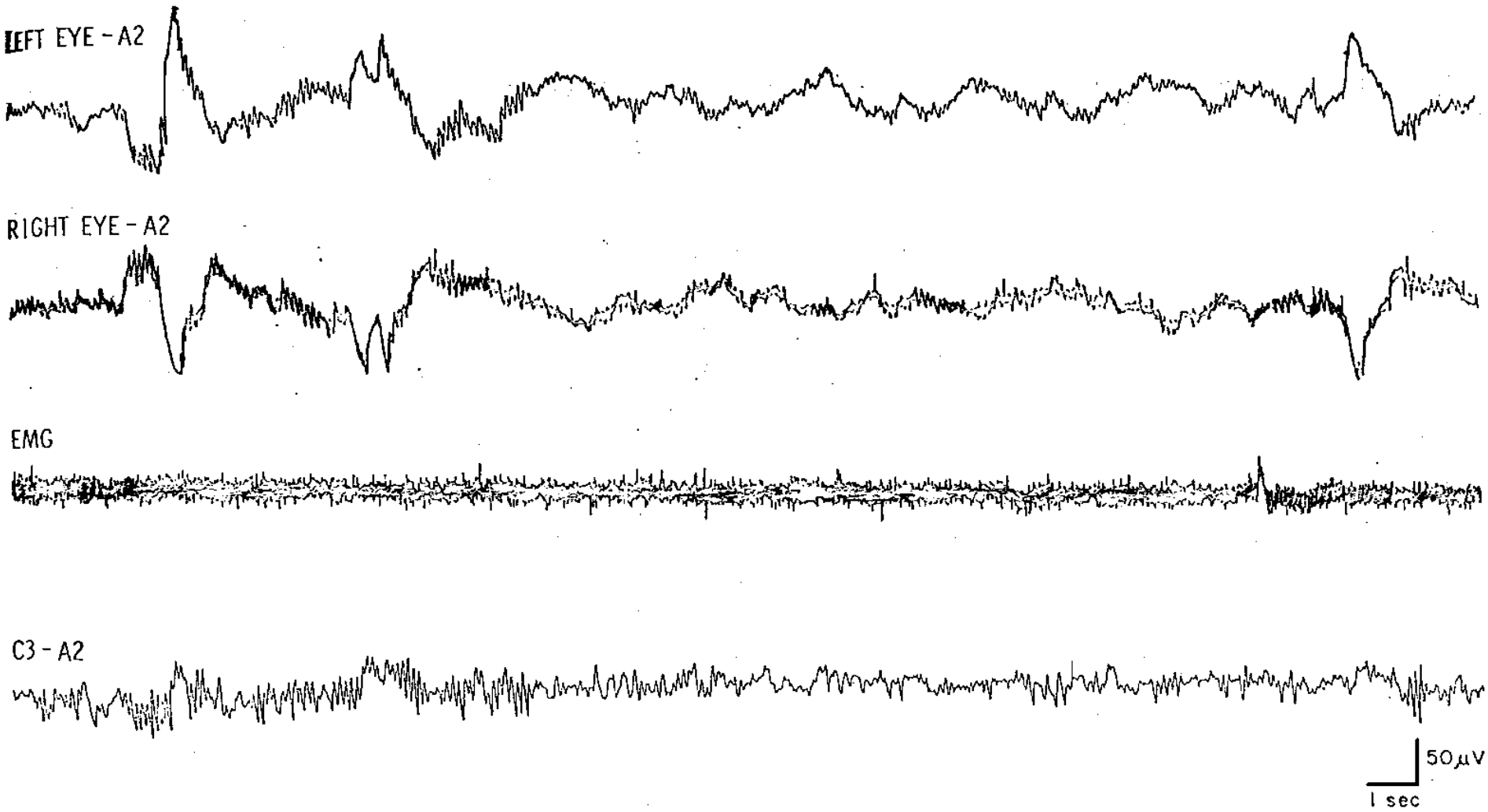


FIGURE 10

Stage 1. This illustrates the transition from Stage W to Stage 1 within a single epoch; REMs and alpha activity at the start of the epoch are followed by slow eye movements and the typical relatively low voltage, mixed frequency EEG of Stage 1 (much activity at 3-4 cps) later in the epoch. There are no vertex sharp waves, which is typical of the early minutes of Stage 1. At the end of the epoch, a REM and a burst of alpha activity signal a return to Stage W, but slightly more than half the epoch is Stage 1, and the epoch is scored accordingly. The relatively elevated EMG is maintained in the transition from Stage W to Stage 1.

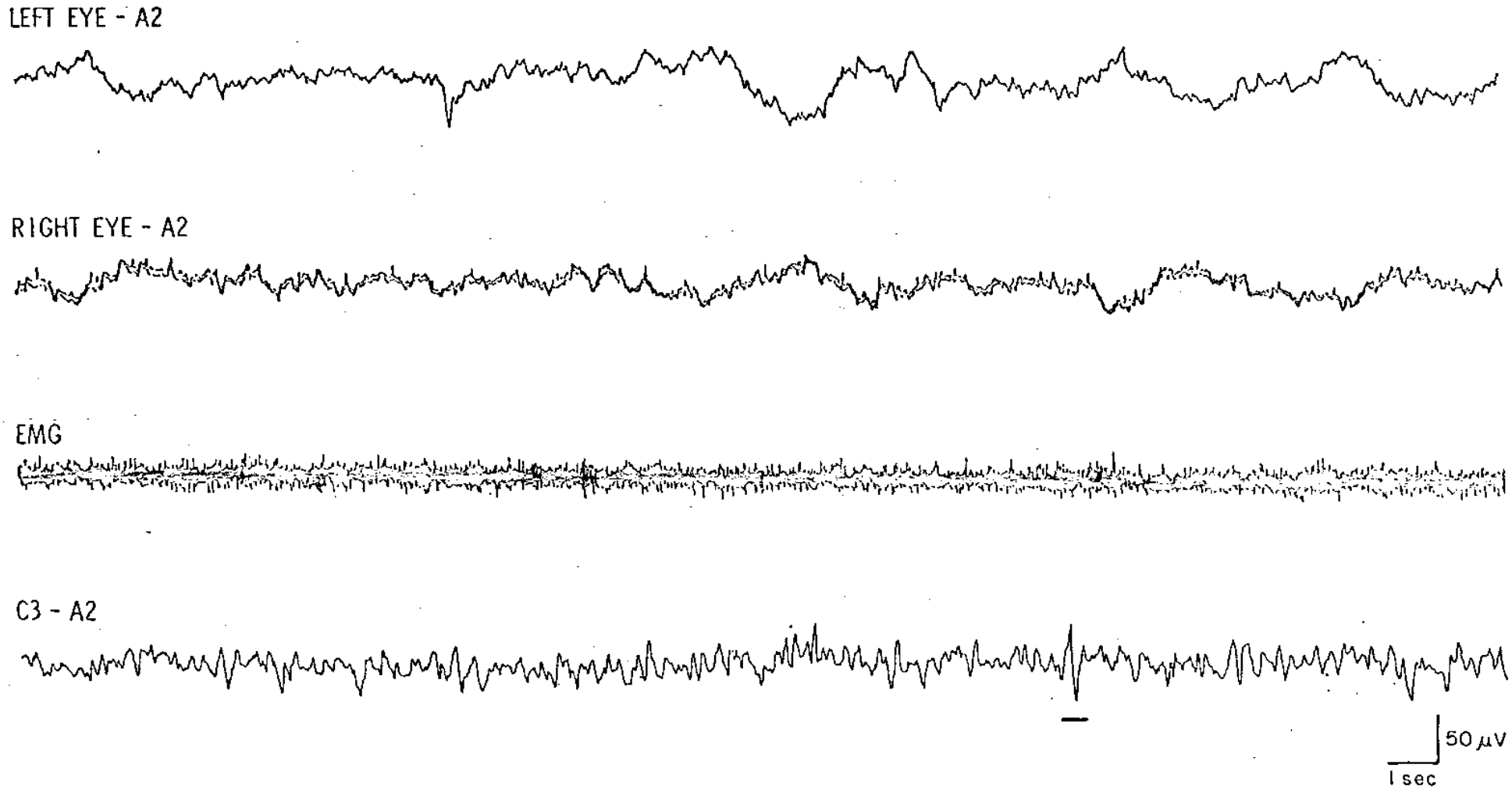


FIGURE 11

Stage 1. This epoch is typical of the early portion of Stage 1. There are slow eye movements and a relatively low voltage, mixed frequency EEG throughout the epoch. Tonic EMG is maintained. There is only one possible vertex sharp wave (underlined).

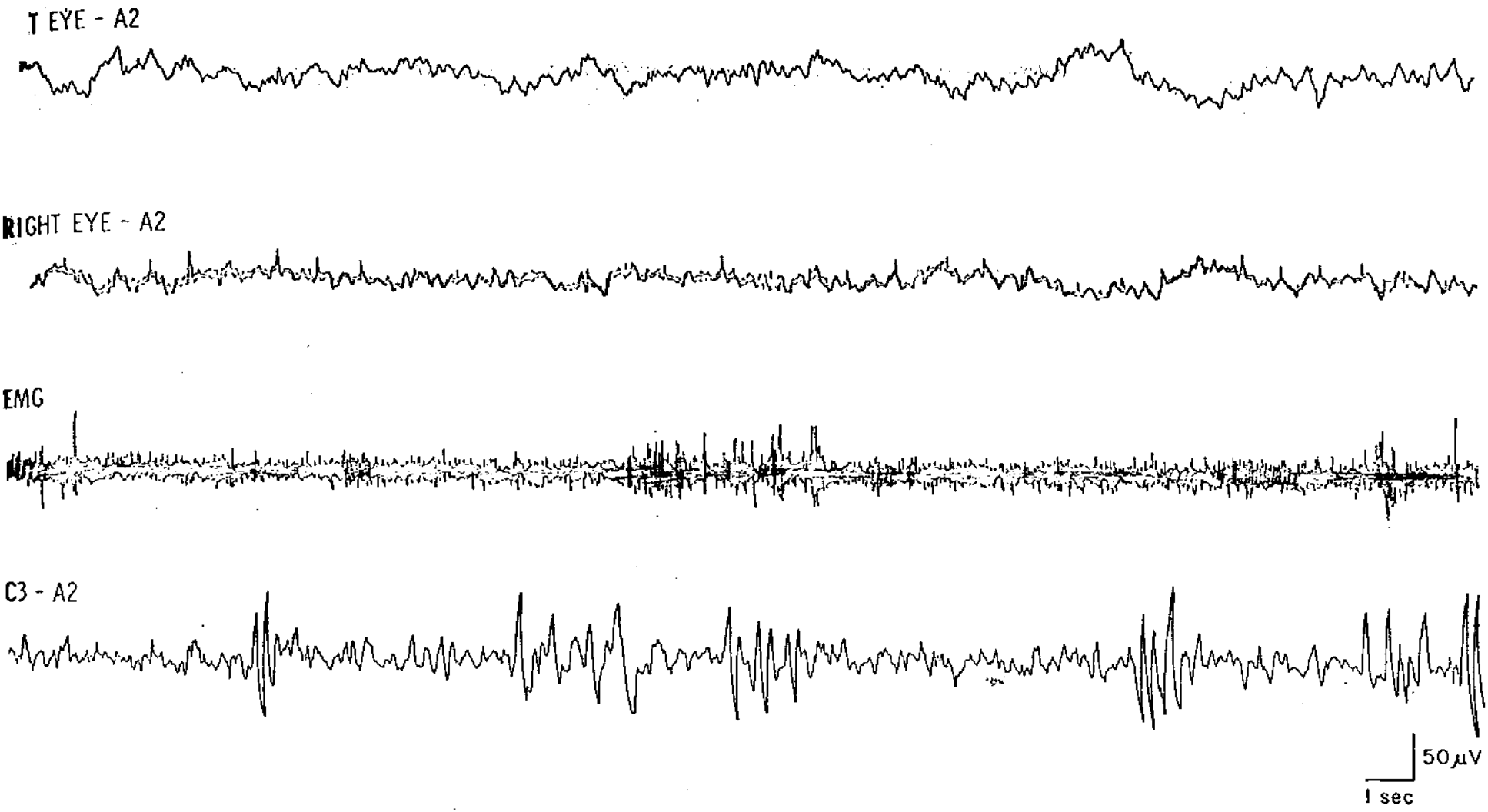


FIGURE 12

Stage 1. This epoch illustrates a later portion of Stage 1 with very prominent vertex sharp waves (more prominent than in most subjects).

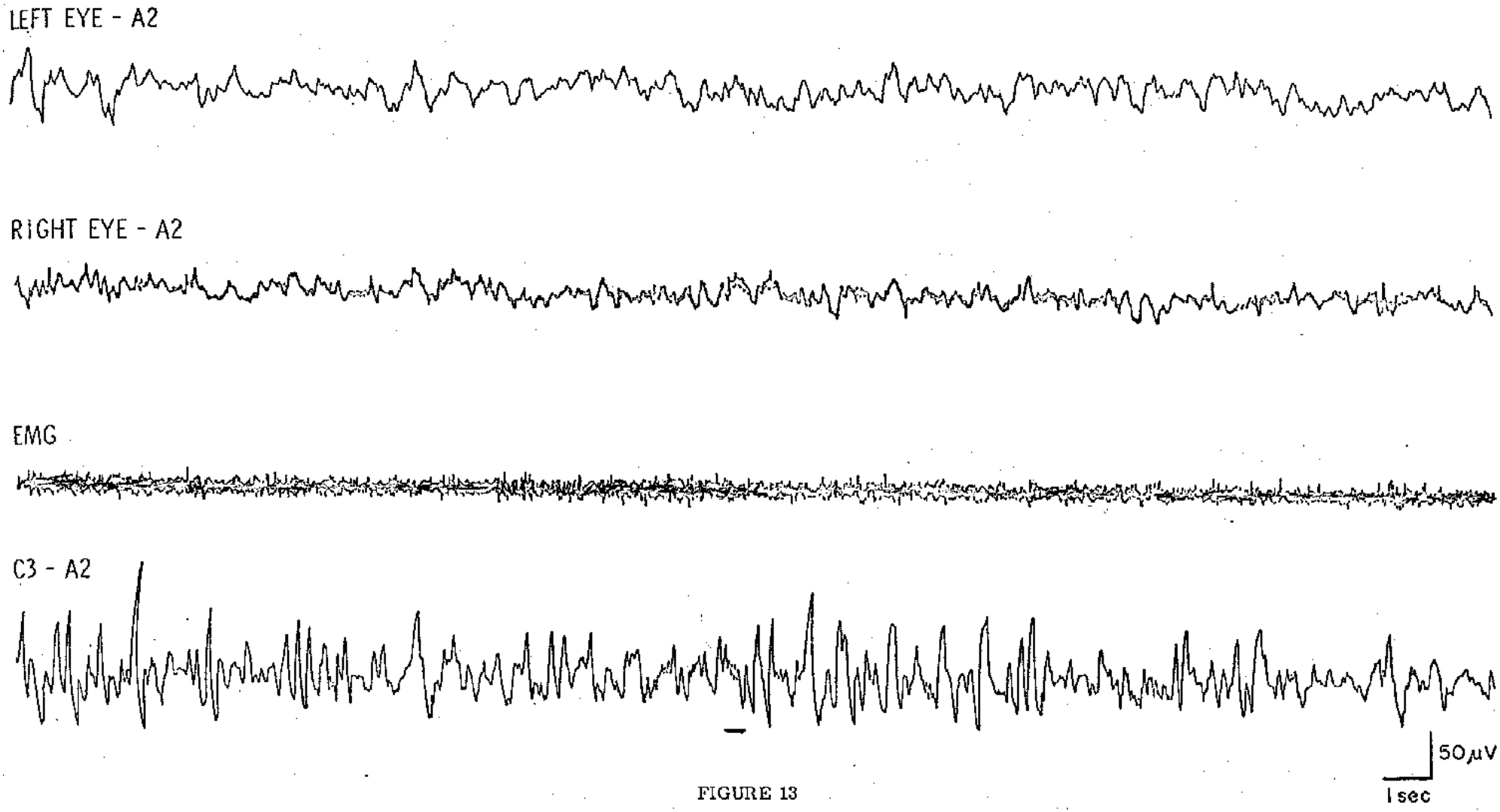


FIGURE 13

Stage 1. This epoch illustrates the beginning of transition from Stage 1 to Stage 2. As is often the case in later portions of Stage 1, slow eye movements stop. Vertex sharp waves are very prominent (more so in this subject than in most subjects). In the middle of the epoch, there is a burst of activity in the 12-14 cps range (underlined), but it does not last for a full half second, and therefore cannot qualify as a sleep spindle for purposes of scoring the epoch. However, the scorer would now be prepared for unambiguous sleep spindles which will follow shortly in subsequent epochs. In such transition records, the differentiation between vertex sharp waves and K complexes may be difficult; conservatism in the interpretation of K complexes is suggested at this point, because sharp wave activity is so obviously present, and unambiguous Stage 2 has not yet appeared.

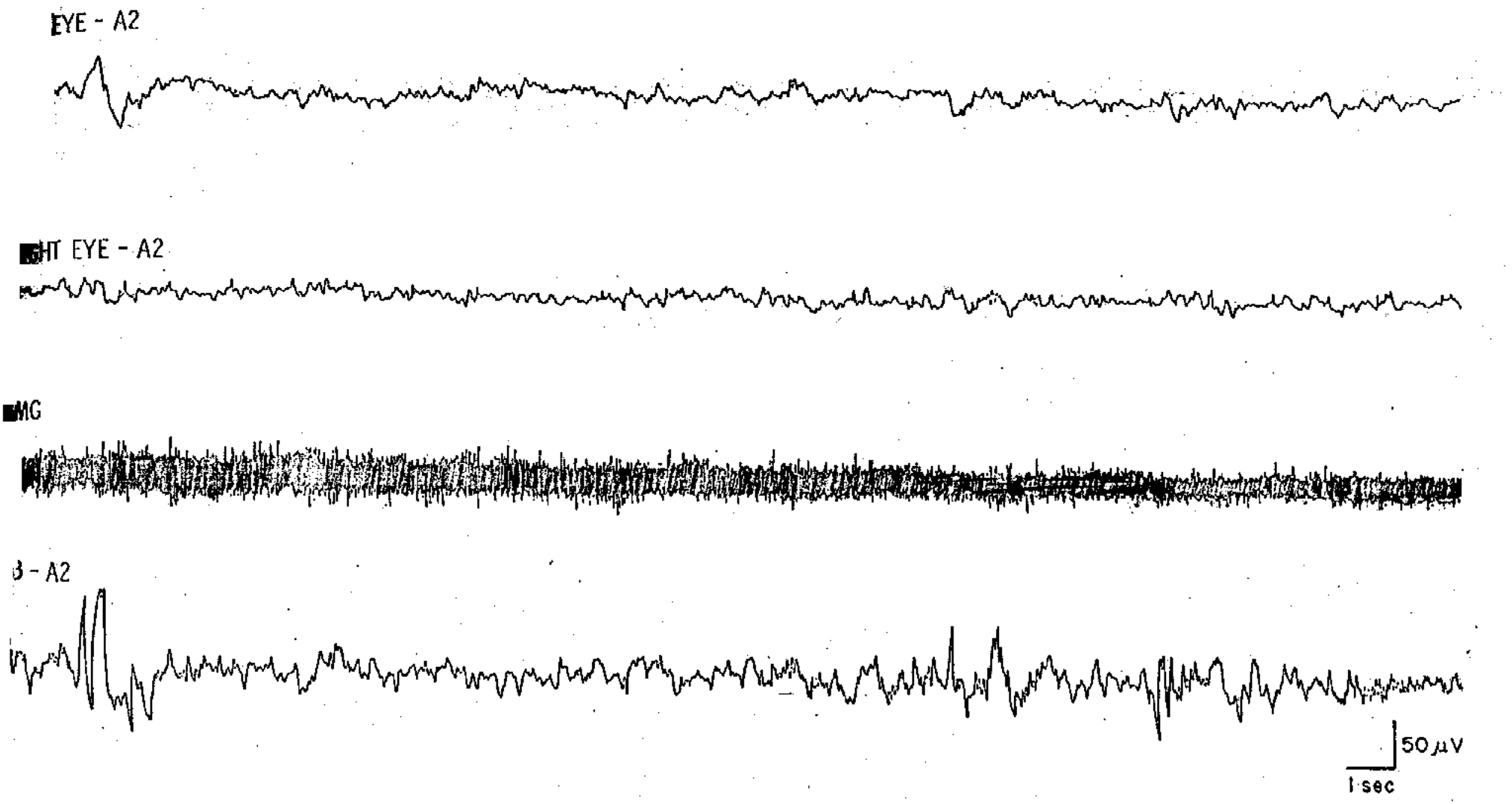


FIGURE 14

Stage 2. This illustrates Stage 2 with relatively elevated tonic EMG. The presence of sleep spindles is unambiguous. EMG calibration 10 μV/c

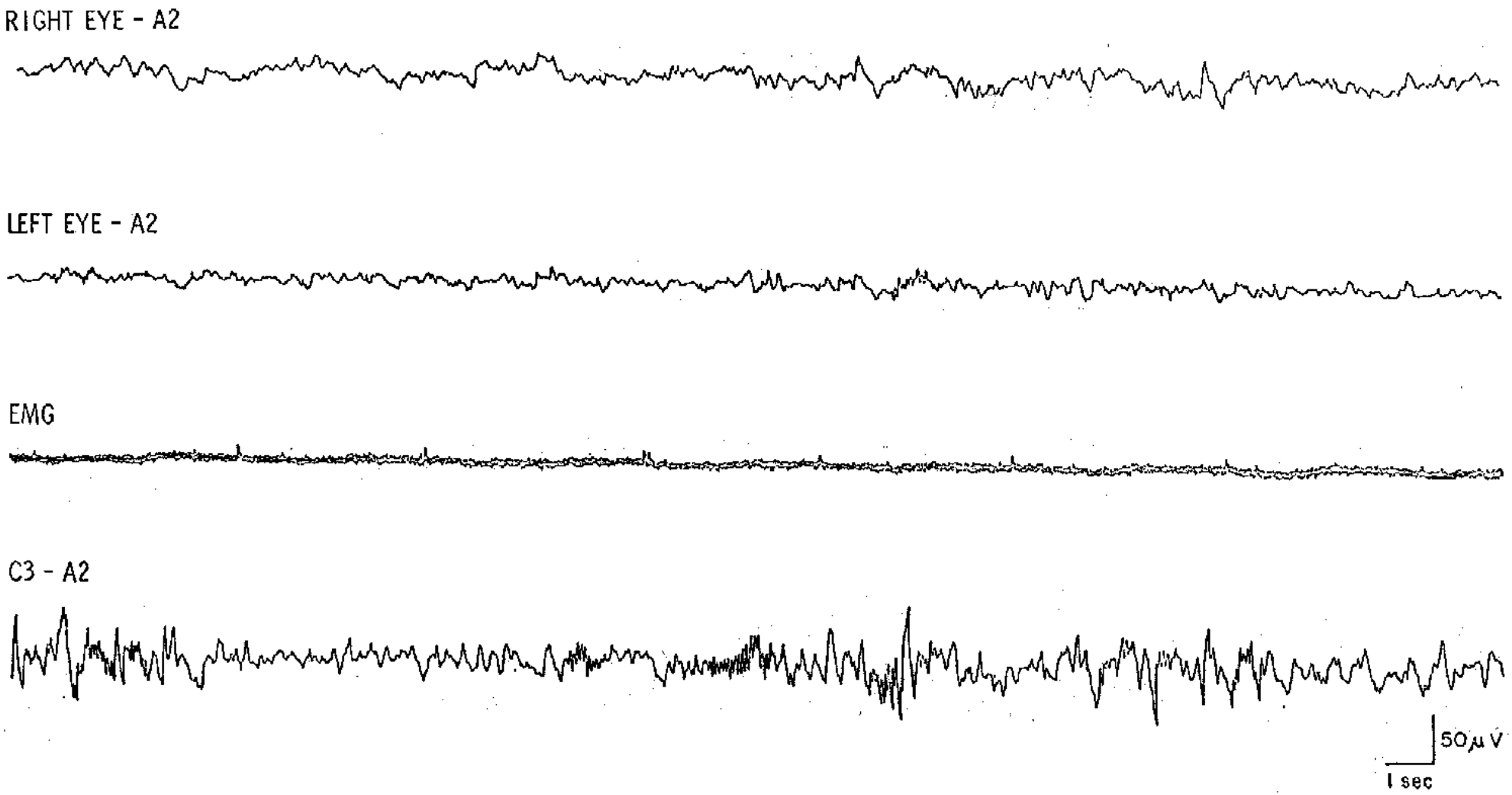


FIGURE 15

Stage 2. This illustrates Stage 2 with tonic EMG at the lowest level attained during the recording session.

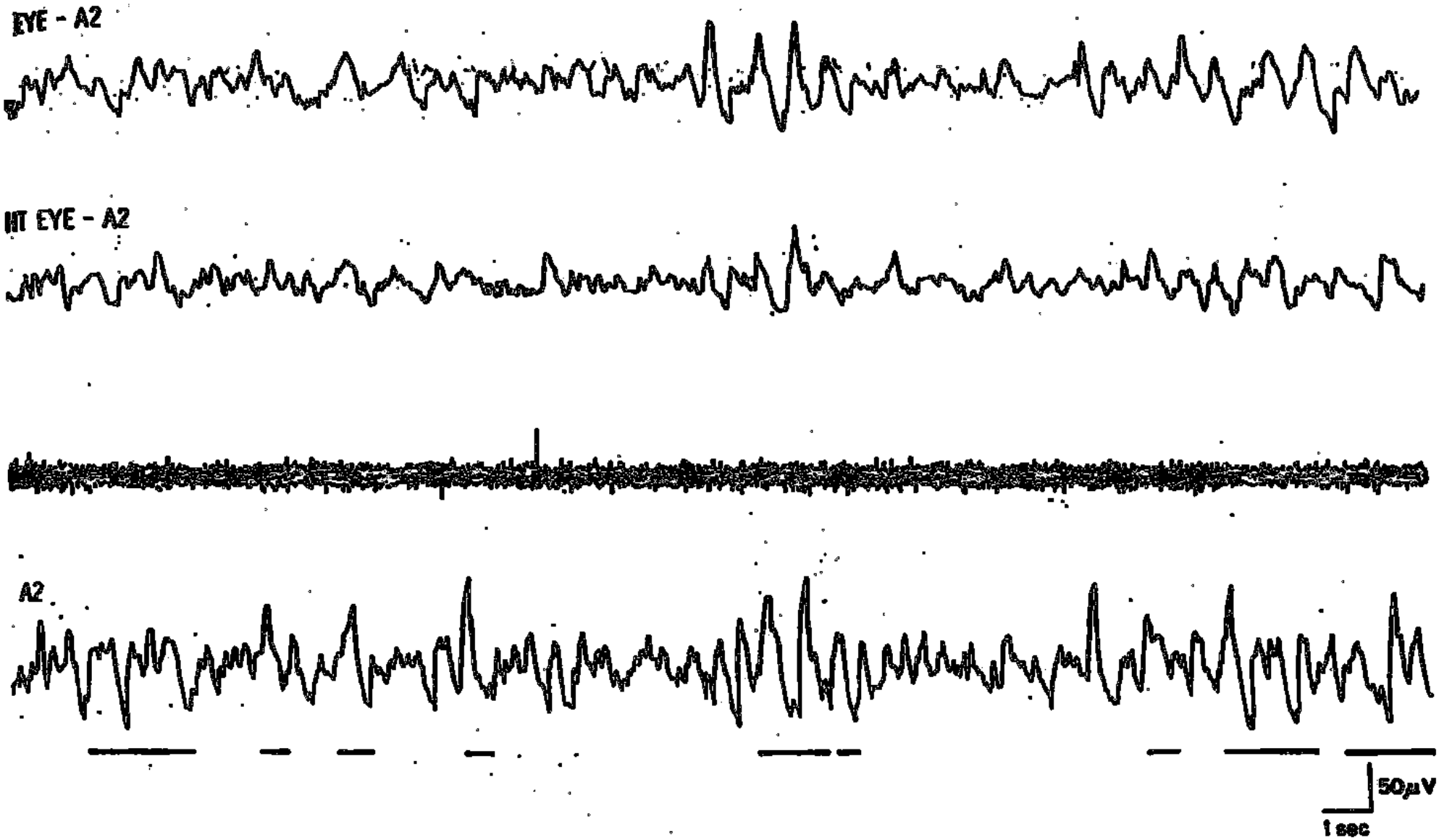


FIGURE 16

Stage 3. This epoch illustrates an unambiguous Stage 3. Acceptable high amplitude, slow wave activity occupies one-third of the record. It is underlined for emphasis in this and all the Stage 3 and Stage 4 epochs which follow.

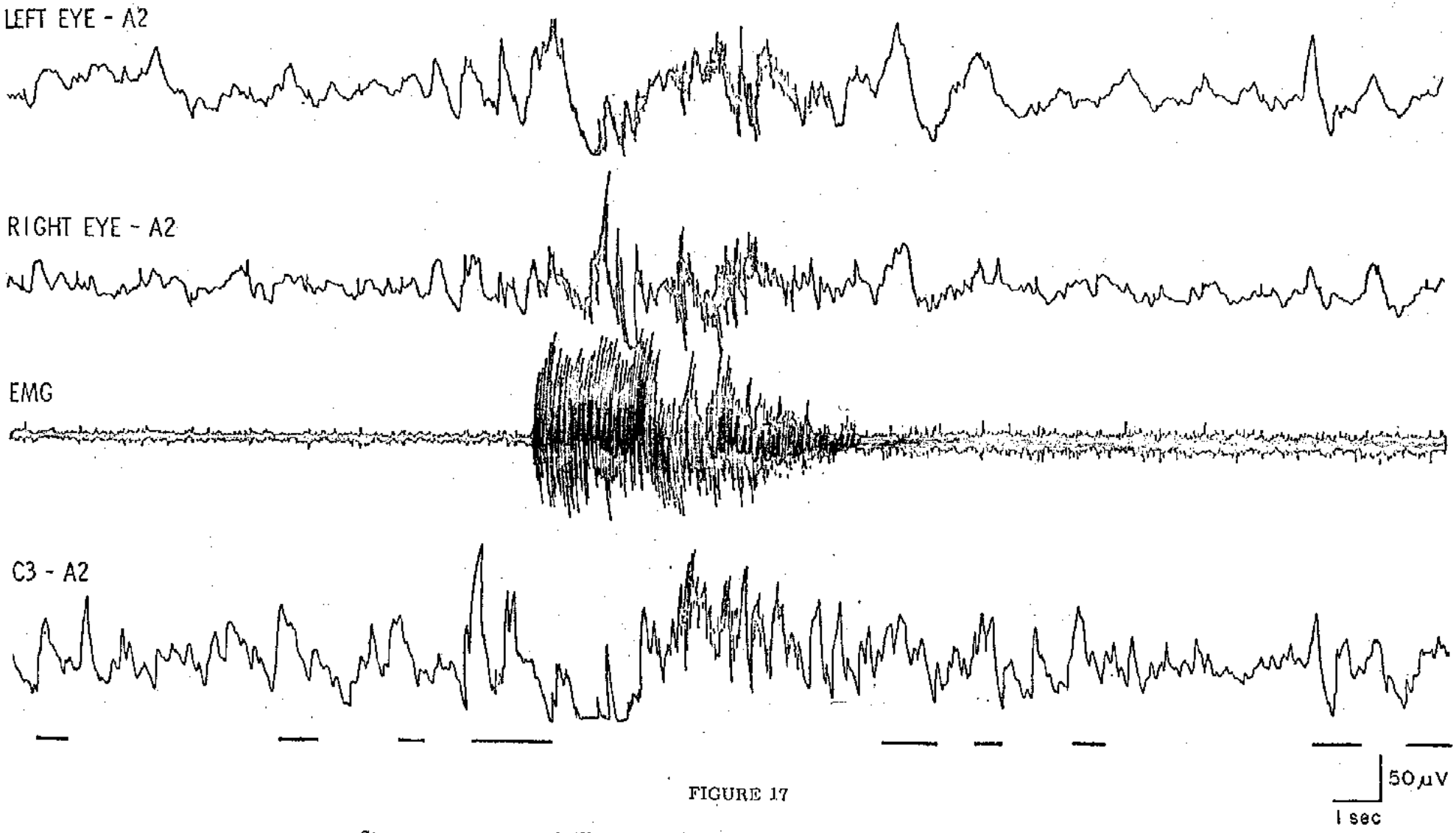


FIGURE 17

Stage ___ epoch illustrates the fact that NREM stages may or may not be accompanied by relatively decreased EMG. Shortly before the middle of the epoch there is a movement arousal which disrupts the prevailing stage only momentarily. Tonic EMG is relatively low before the movement arousal and relatively high following it, yet the record is Stage 3 throughout.

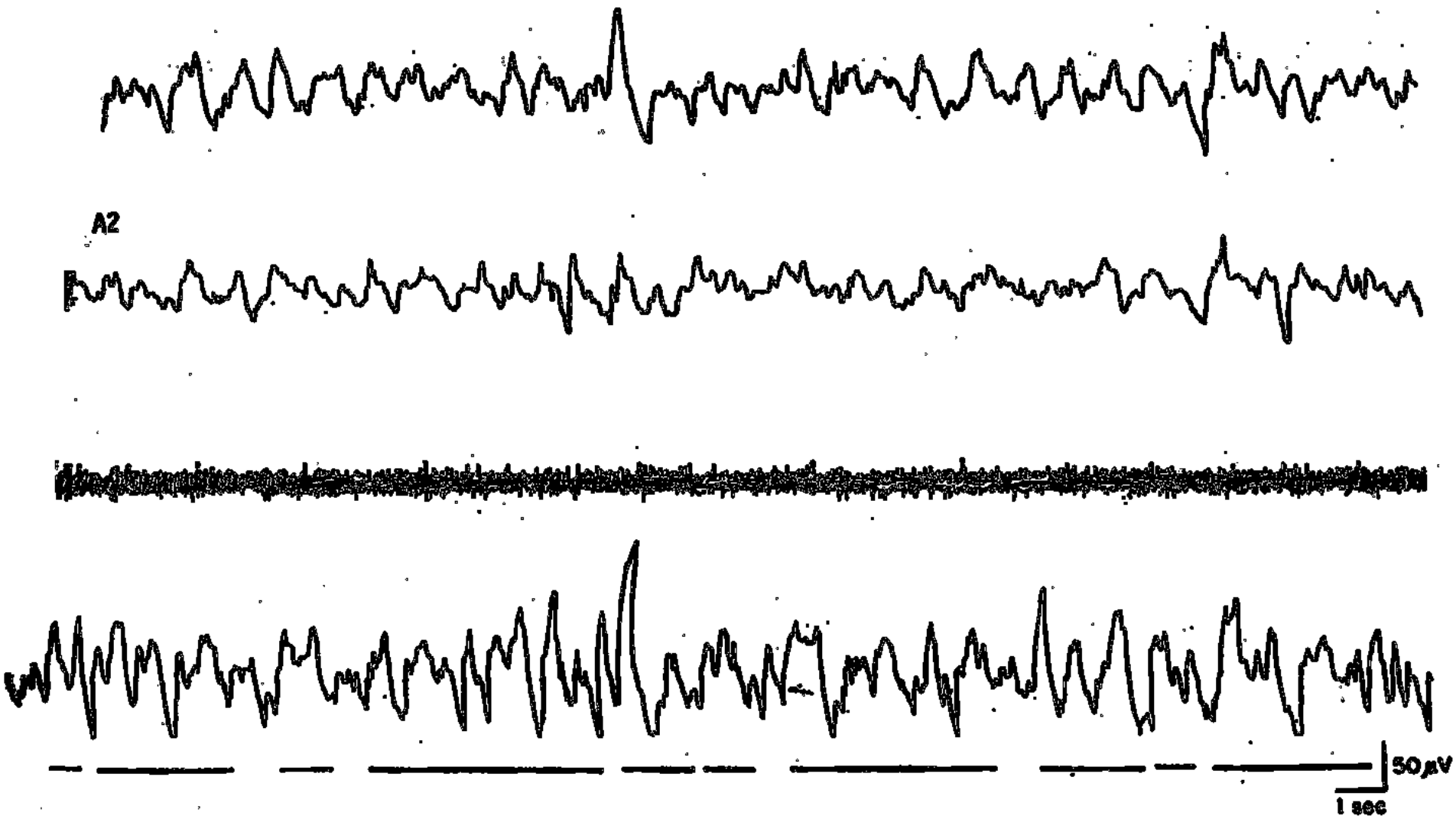


FIGURE 18

Stage 4. This represents a typical Stage 4 epoch. Note that sleep spindles may be present in Stage 4.

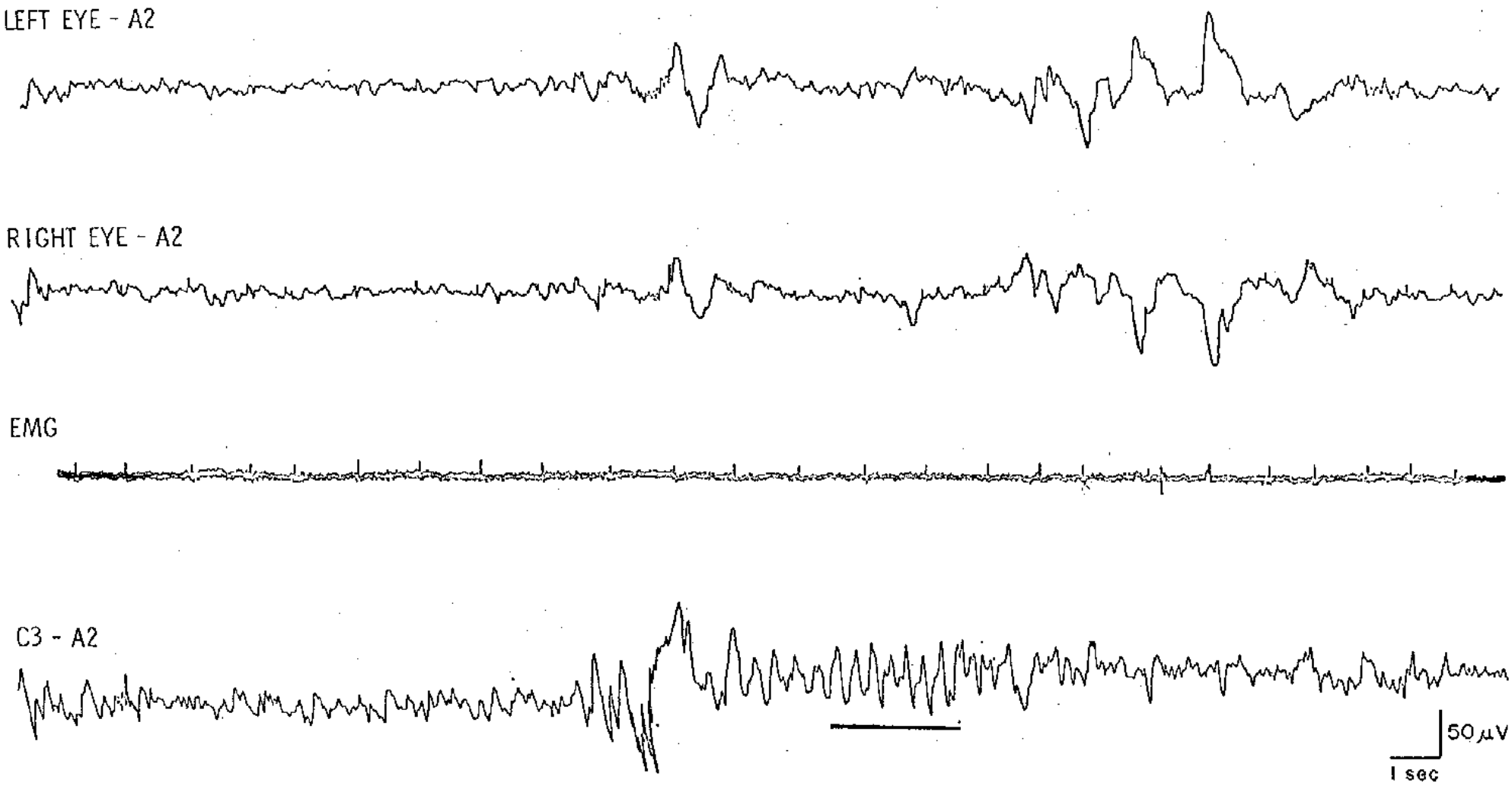


FIGURE 19

Stage REM. This epoch illustrates a transition between Stage 2 and Stage REM. The record had been Stage 2 for some time prior to this epoch. Just before the midpoint of the epoch, there is a clear sleep spindle followed by a K complex. Following the K complex are clear saw-tooth waves (underlined), which herald the appearance of REMs during the last third of the epoch. (Note that not all the saw-tooth waves have the distinctive notched appearance.) Stage REM is considered to have begun immediately after the end of the K complex, and to continue for the remainder of the epoch. The interval of Stage REM occupies just over 50% of the epoch; hence the entire epoch is considered Stage REM. EMG is at the lowest level of the recording session.

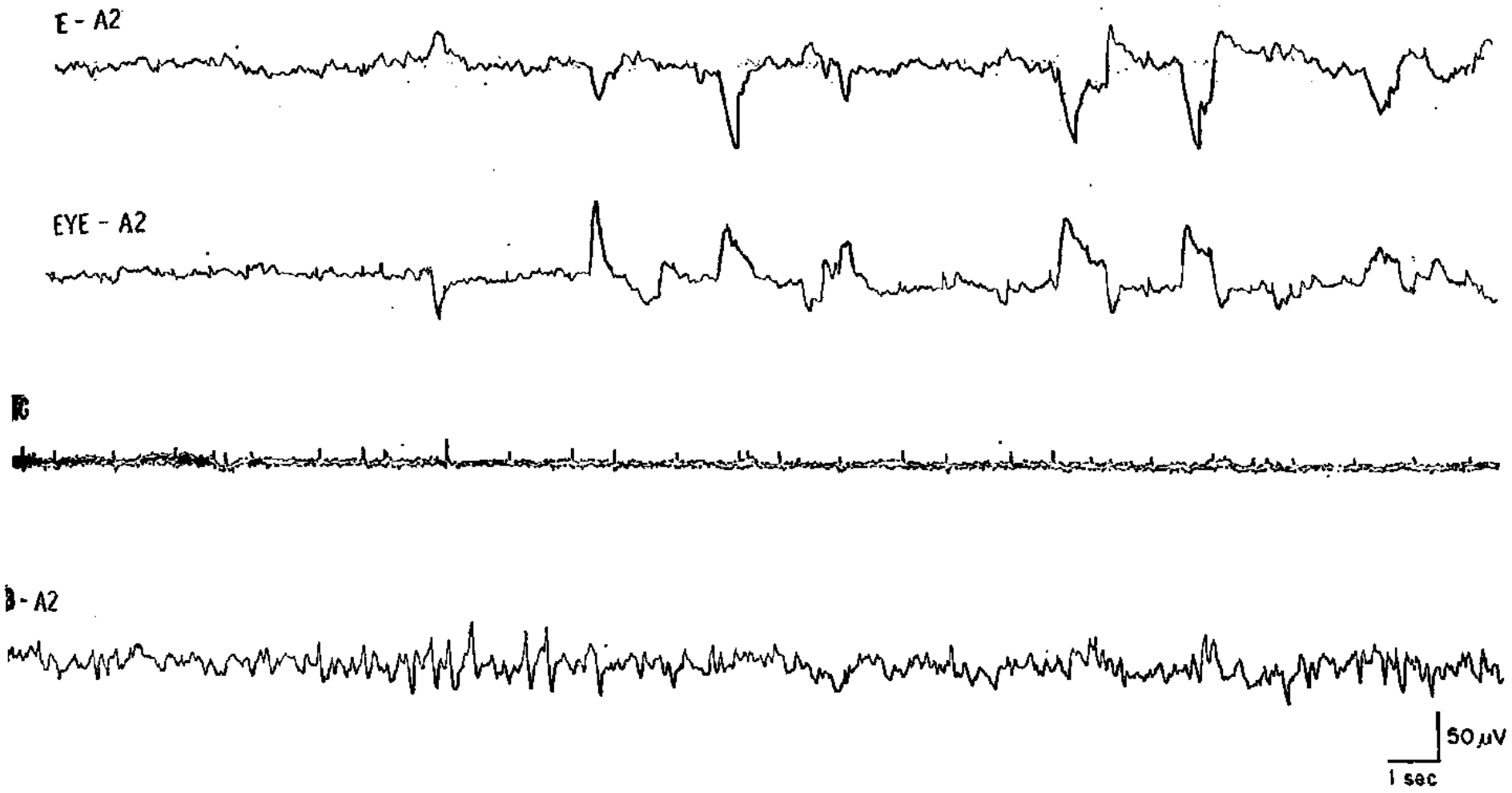


FIGURE 20

Stage REM. This is an unambiguous Stage REM with relatively low voltage, mixed frequency EEG, REMs, and EMG at the lowest level of the recording session. Note that saw-tooth waves may or may not accompany REMs.

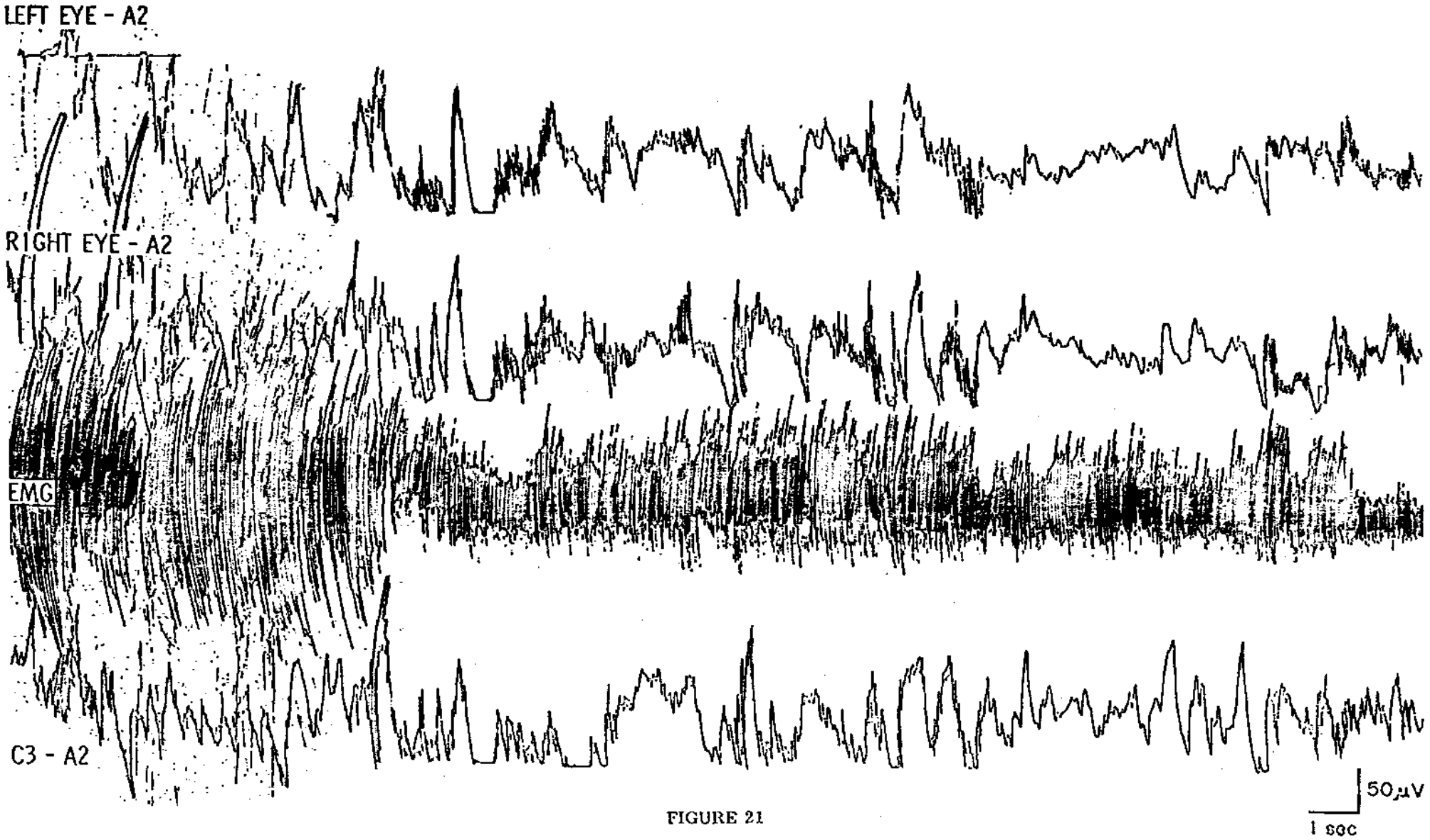


FIGURE 21

MT. Although there is clear high amplitude, slow wave activity near the end of the epoch, the greatest portion of the epoch is obscured by the movement artifact and is therefore scored as MT rather than as any stage.

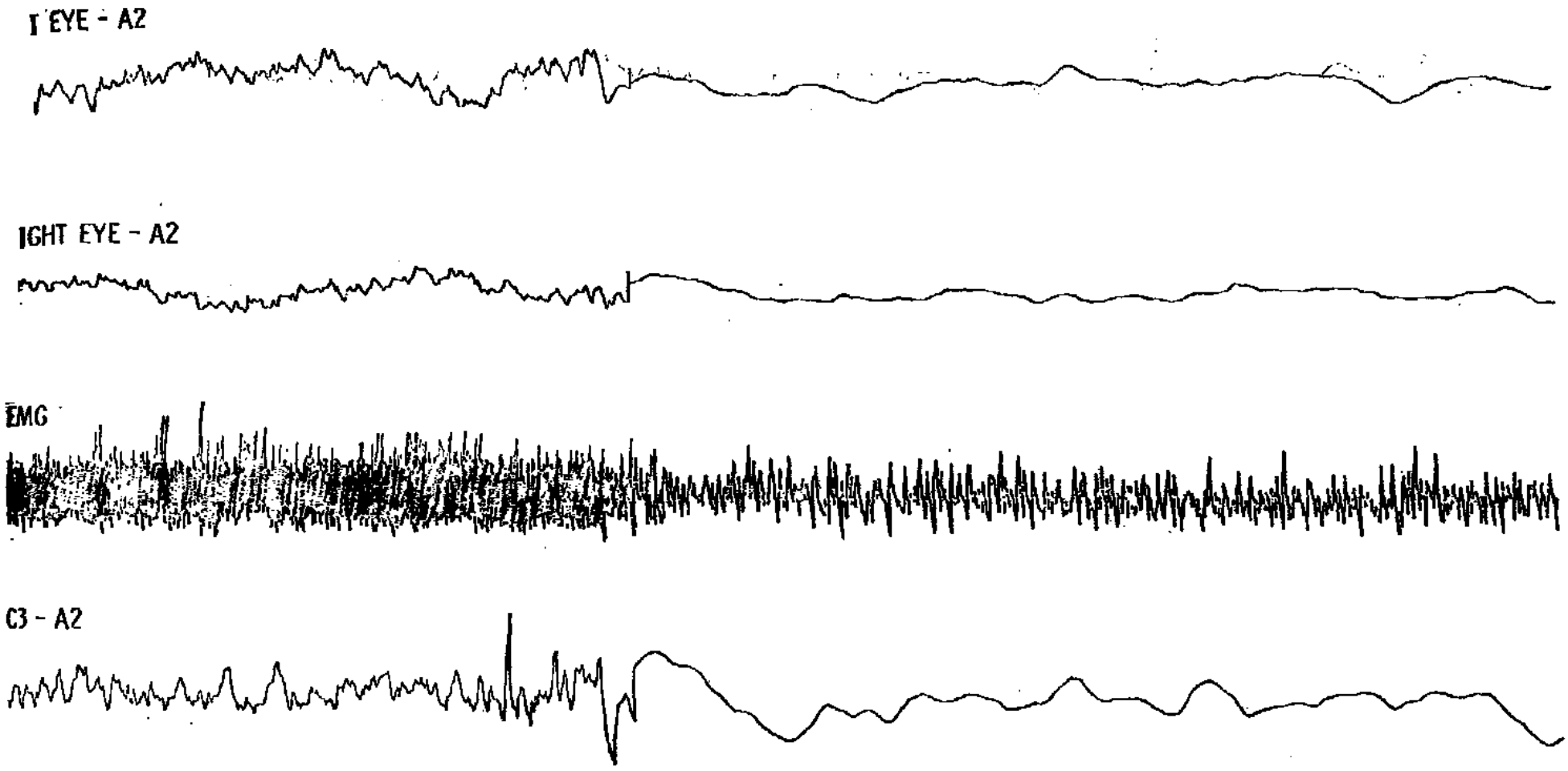


FIGURE 22

This epoch illustrates a test for 60 cycle artifact. During the latter portion of the epoch, the paper speed is changed from 10 mm/sec to 100 mm/sec. At the latter paper speed, 60 cps artifact would show up as 6 very regular sinusoidal waves per cm; such activity is virtually absent in the record. This illustrates that mental-submental EMG can be recorded at high gains without artifact if proper electrode attachment is used. Large (1 in. diameter) lead electrodes were used. The EMG recording was made at a gain of 10 μV/cm and a time constant of 0.03 sec. There was no filtering of the EMG record (on the Beckman Type R, the coupler filter position was #1, and the amplifiers were run with the highs in). On initial electrode application, the inter-electrode resistance for the EMG electrodes was 500 ohms.

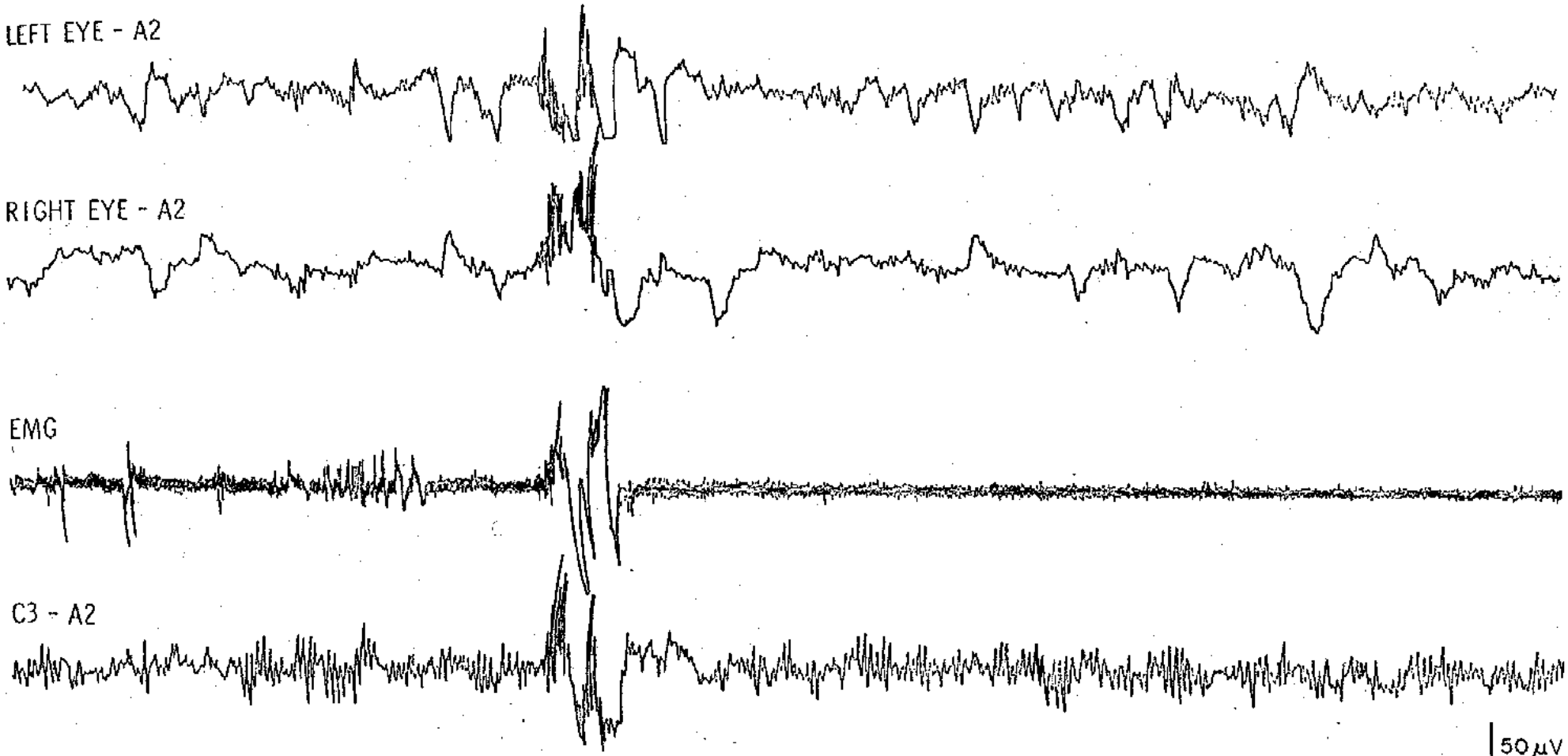


FIGURE 23

Stage W. This is an unambiguous Stage W with relatively continuous alpha, muscle tension artifacts, and REMs.

FIGURES 23 - 32

Epochs from the various stages of subject 2 are presented. The subject was a 21 year old, normal, male college student. All the tracings are from the same night and were recorded on a Beckman Type R Dynograph. Each tracing represents a 30 sec epoch recorded at a paper speed of 10 mm/sec. For the eye movement and EEG channels calibration was 50 μV/cm and the time constant was 0.3 sec. For the EMG channel, the time constant was 0.03 sec. In Figs. 23-27 the calibration for the EMG channel was 50 μV/cm. In Figs. 28-32, the EMG calibration was 10 μV/cm.

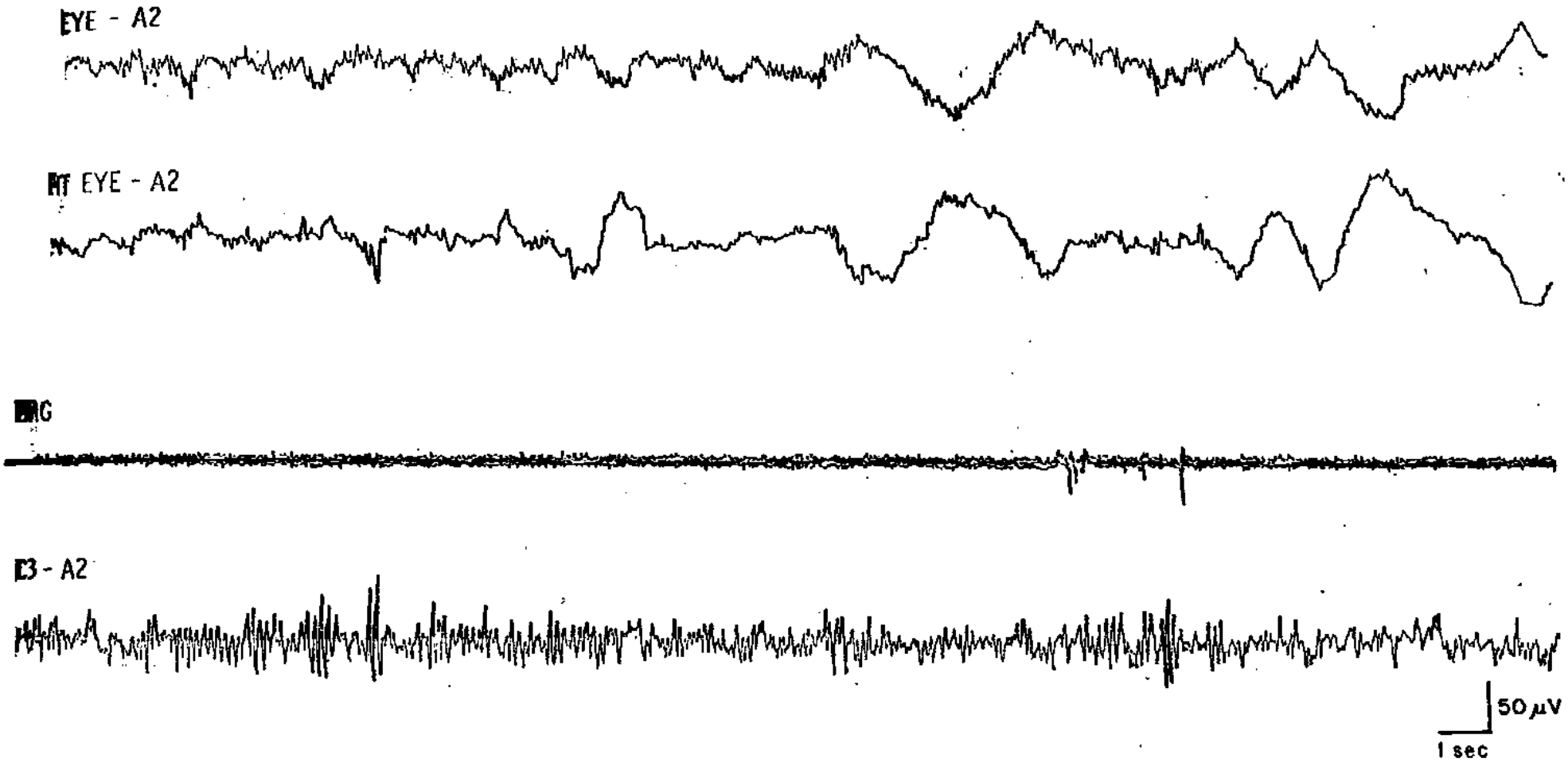


FIGURE 24

Stage W. The record is clearly Stage W in that more than half the epoch is occupied by alpha activity. However, the occurrence of slow, pendular eye movements in the second half of the epoch heralds the impending appearance of Stage 1. The slow eye movements typically appear several seconds to a few minutes before the development of unambiguous Stage 1. This epoch constitutes the first of a series of 3 consecutive epochs which compactly illustrate the typical transition from Stage W to Stage 1.

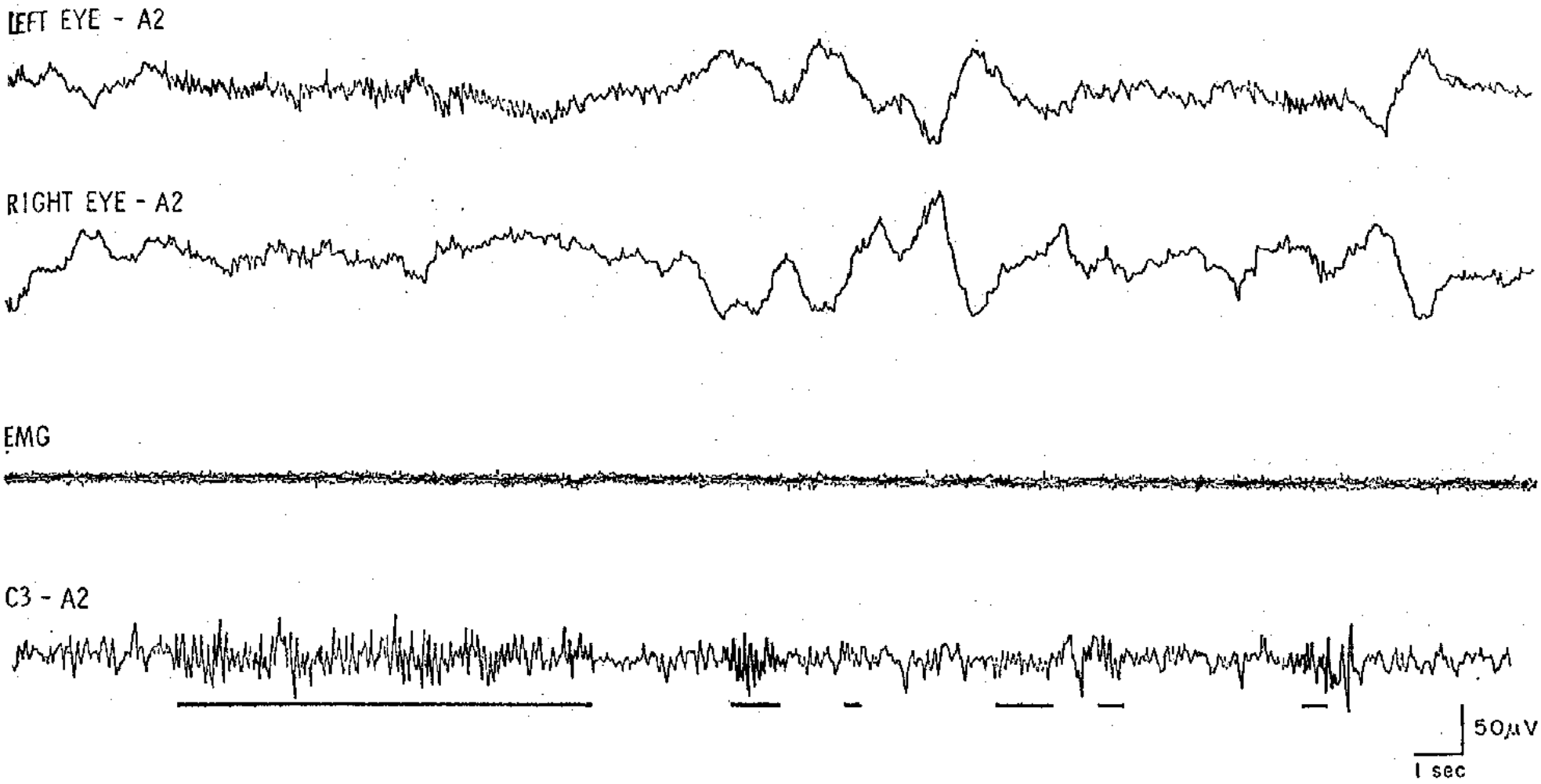


FIGURE 25

Stage 1. This epoch further illustrates the transition from Stage W (the preceding epoch) to Stage 1. Although alpha activity is still abundant, it accounts for only about one-third of the epoch (underlined). The intervals between the alpha activity show relatively low voltage, mixed frequency activity. Note how the slow eye movements tend to be associated with the disappearance of alpha activity.

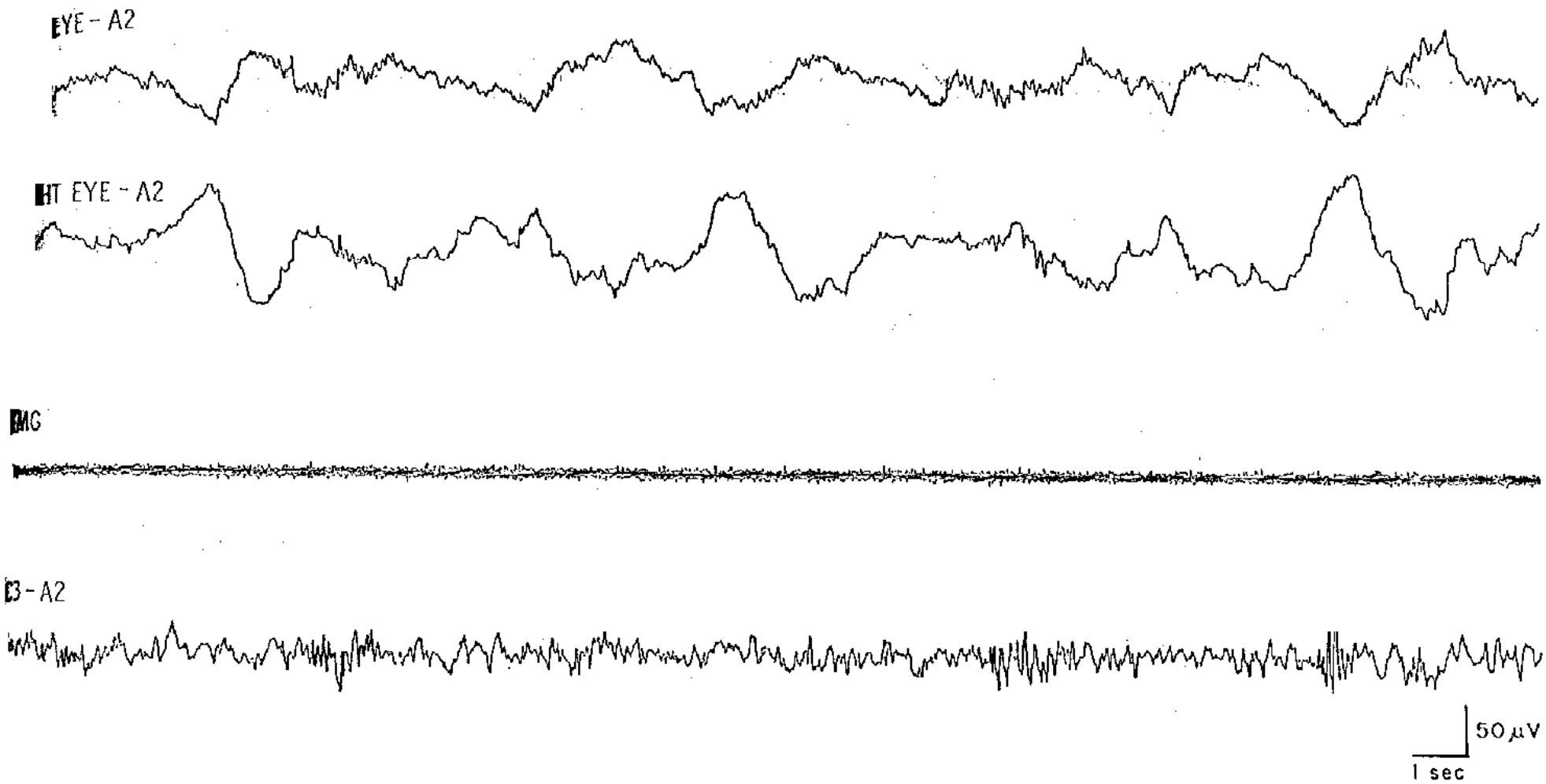
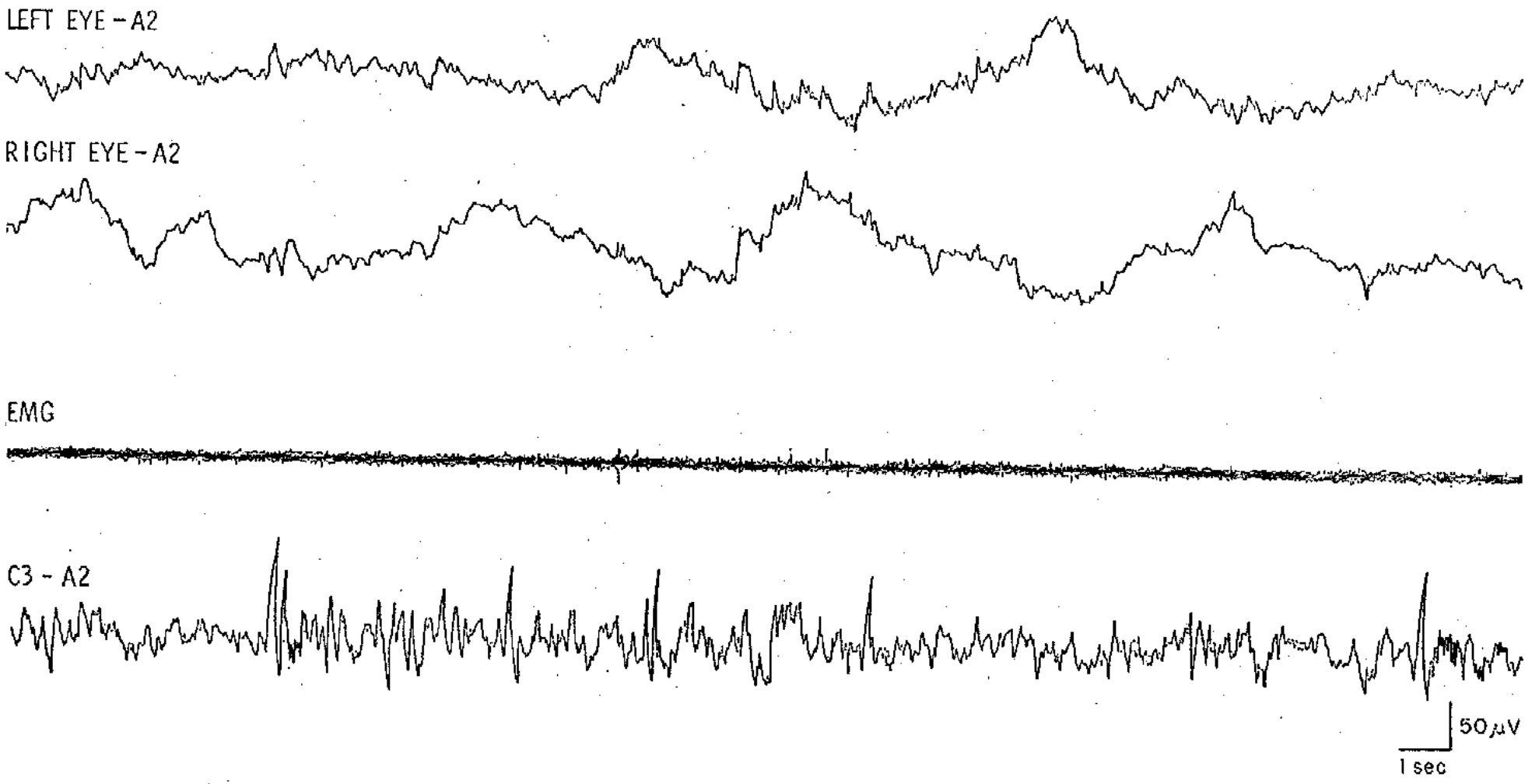


FIGURE 26

Stage 1. Stage 1 is now firmly established and alpha activity is almost absent. Vertex sharp waves appear near the end of the epoch.



Stage 2. In Stage 2 epochs which follow soon after Stage 1, as this one does, vertex sharp waves may be very abundant. These vertex sharp waves should not be confused with the high amplitude activity of Stage 3. The sharp waves can usually be distinguished with ease by their faster frequency, their prominence at the vertex (not possible here because only one channel of EEG was recorded), by the fact that they stand out against a background of much lower voltage activity, and by their monophasic appearance. The emergence of high amplitude, slow wave activity is usually accompanied by an overall increase in background amplitude. Also note that most of the high amplitude activity in this sample is not slow enough to meet the 2 cps criterion for acceptable high amplitude activity in the scoring of Stages 3 and 4. The prominent slow eye movements persist from the preceding Stage 1.

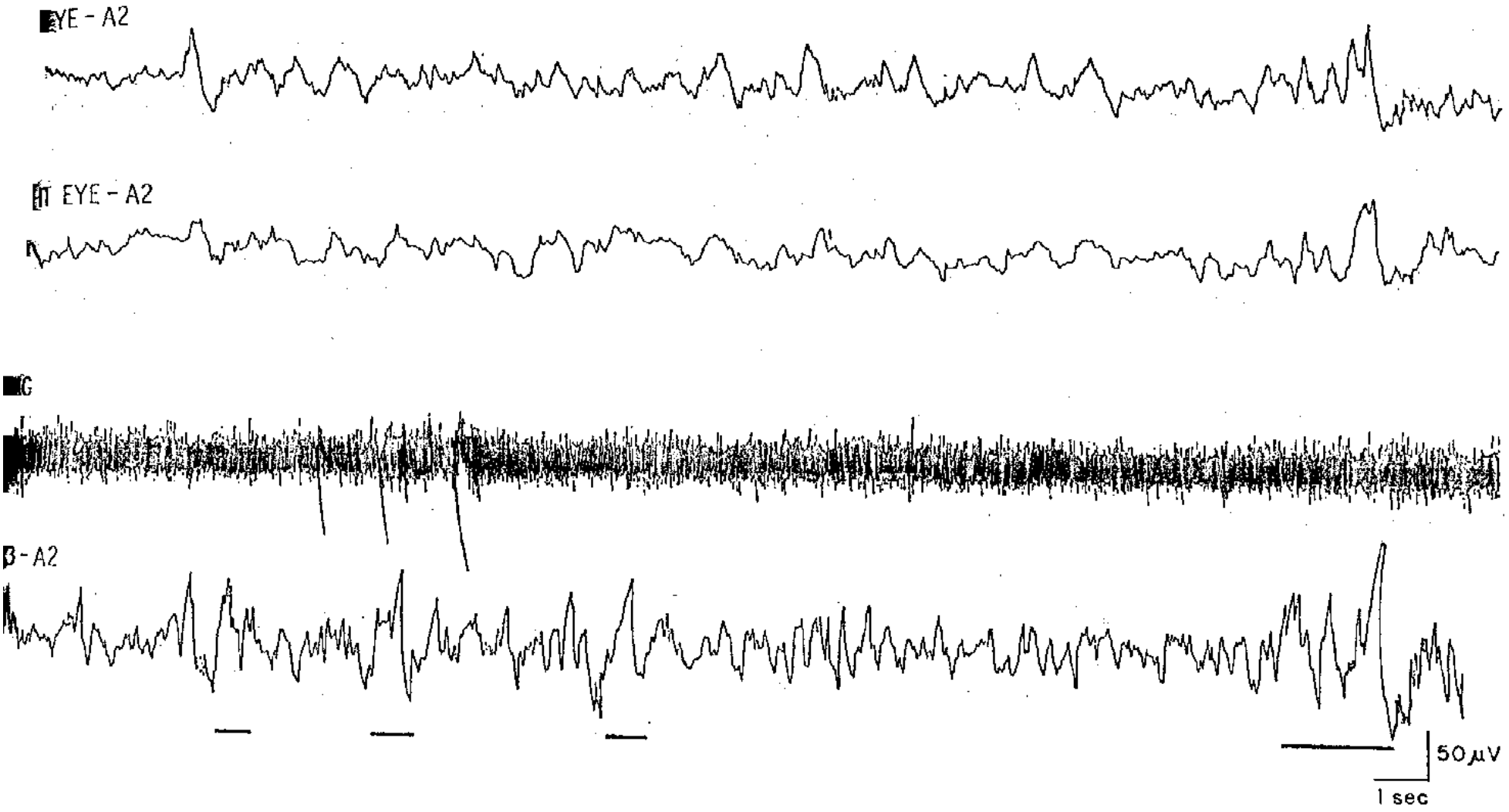


FIGURE 28

Stage 2. This epoch is almost borderline between Stages 2 and 3; approximately 15% of the epoch is occupied by acceptable high amplitude, slow wave activity.

EMG calibration. 10μV/c

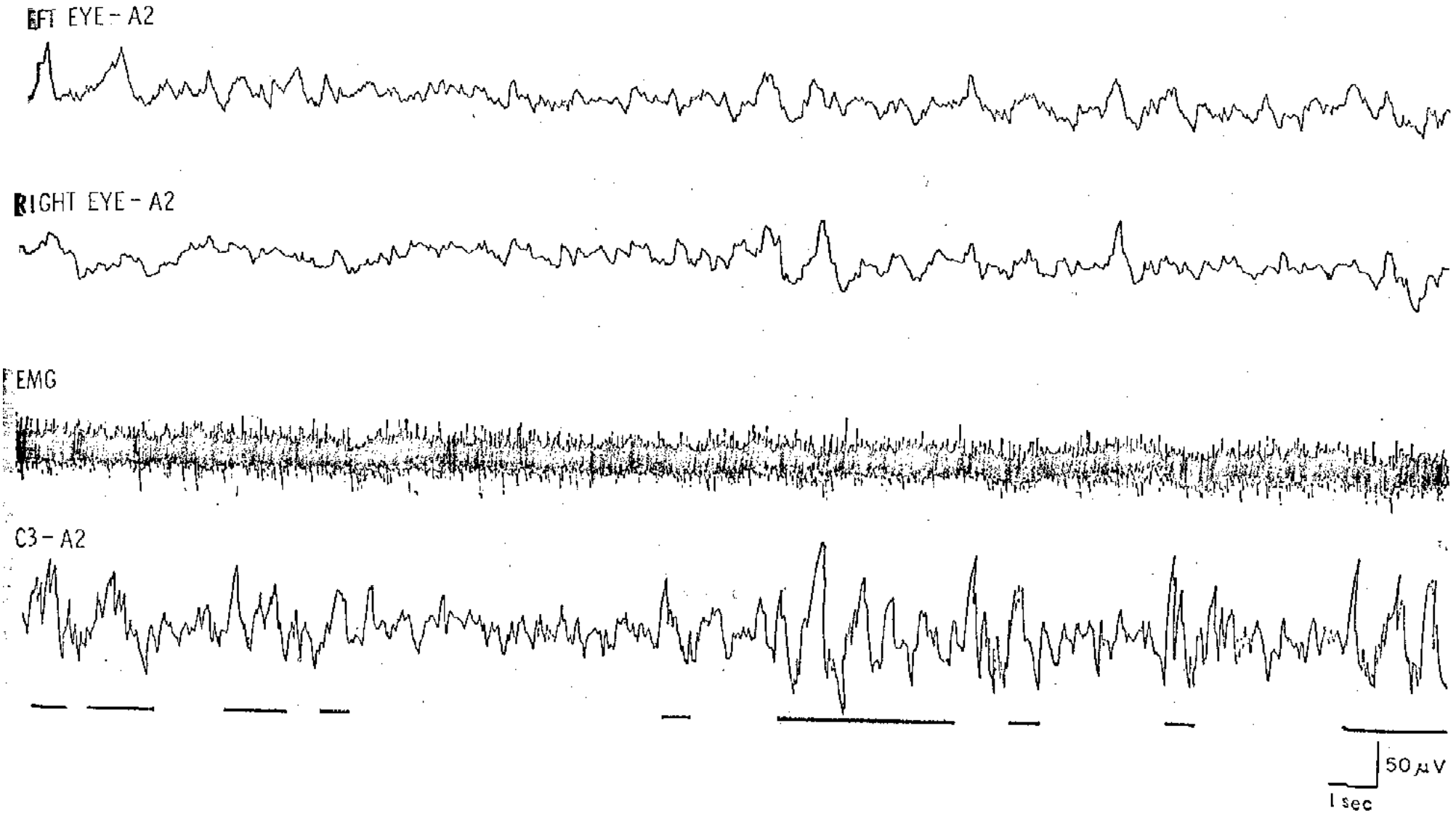


FIGURE 29

Stage 3. This is an unambiguous Stage 3 epoch.

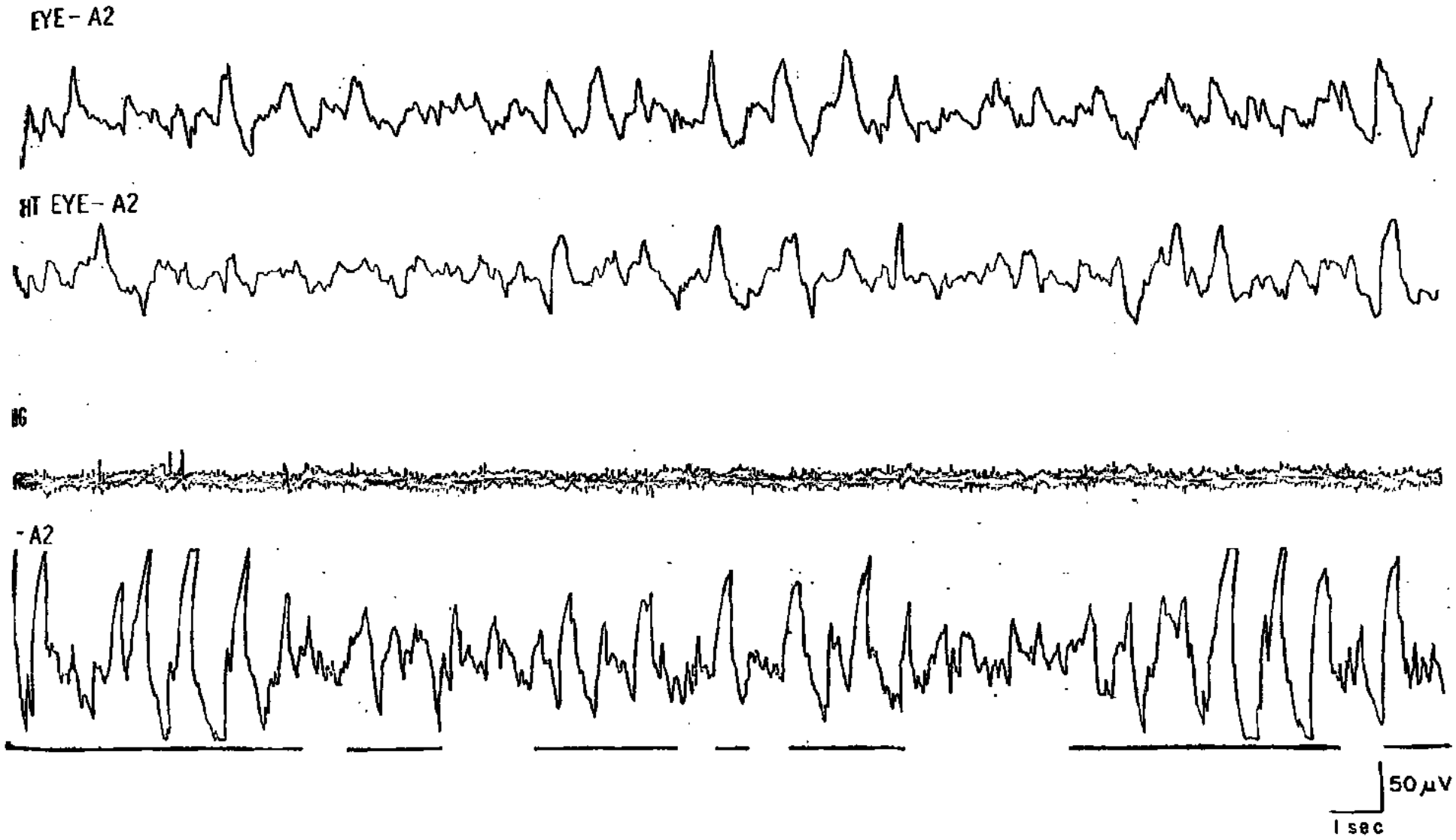


FIGURE 30

Stage 4. This is an unambiguous Stage 4 epoch.

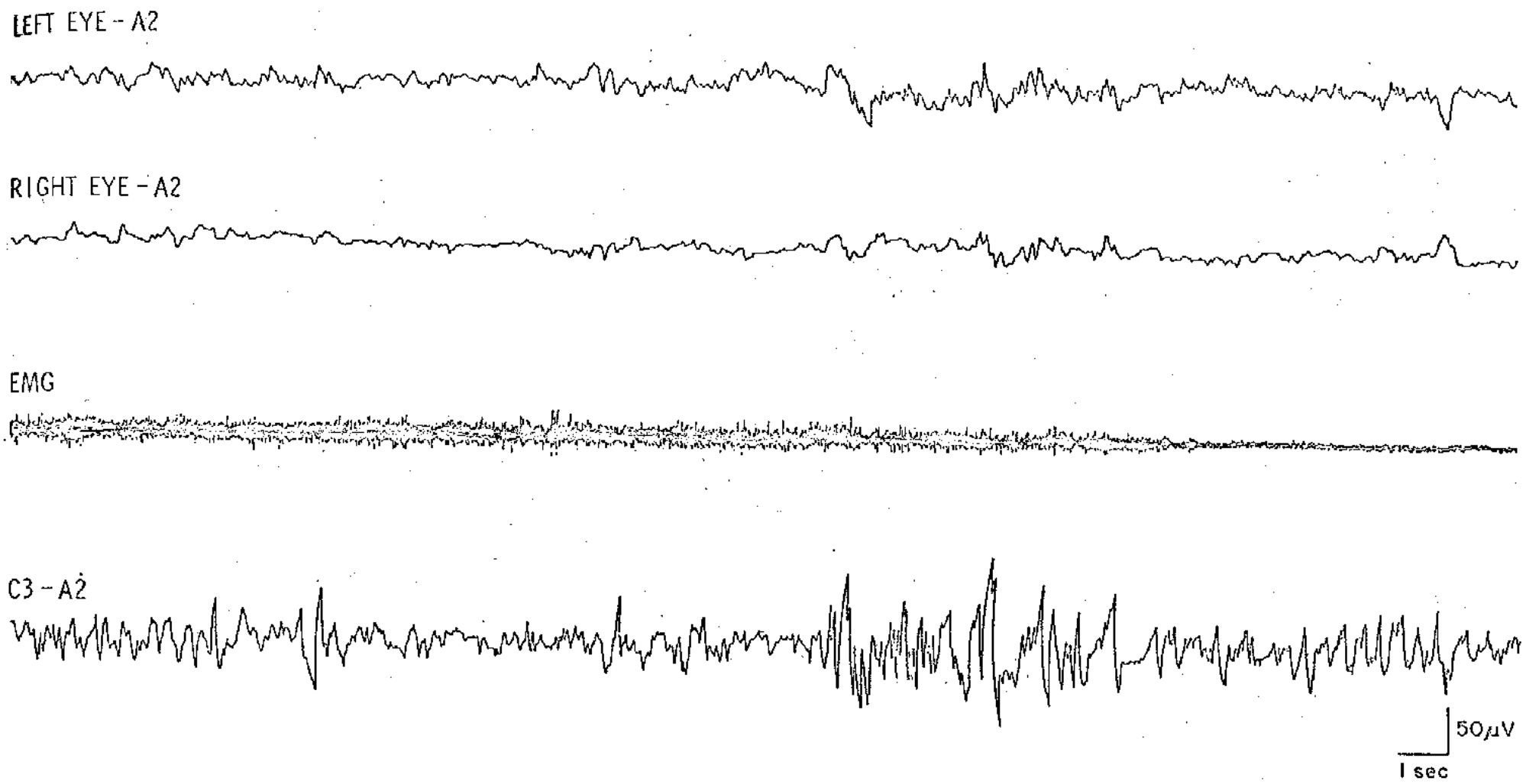


FIGURE 31

Stage 2. This epoch illustrates a clear transition between Stage 2 and Stage REM. The sleep spindles and K complexes shortly following the middle of the epoch indicate Stage 2. (The preceding epoch was also Stage 2.) Toward the end of the epoch there is a clear decrease of EMG, which then reaches the lowest level attained during the recording session. The EMG decrease is shortly followed by rudimentary saw-tooth waves and a single REM. The part of the epoch which would satisfy the requirements of Stage REM begins at the point of the EMG decrease. Inasmuch as this constitutes less than one-half the epoch, the entire epoch is scored Stage 2.

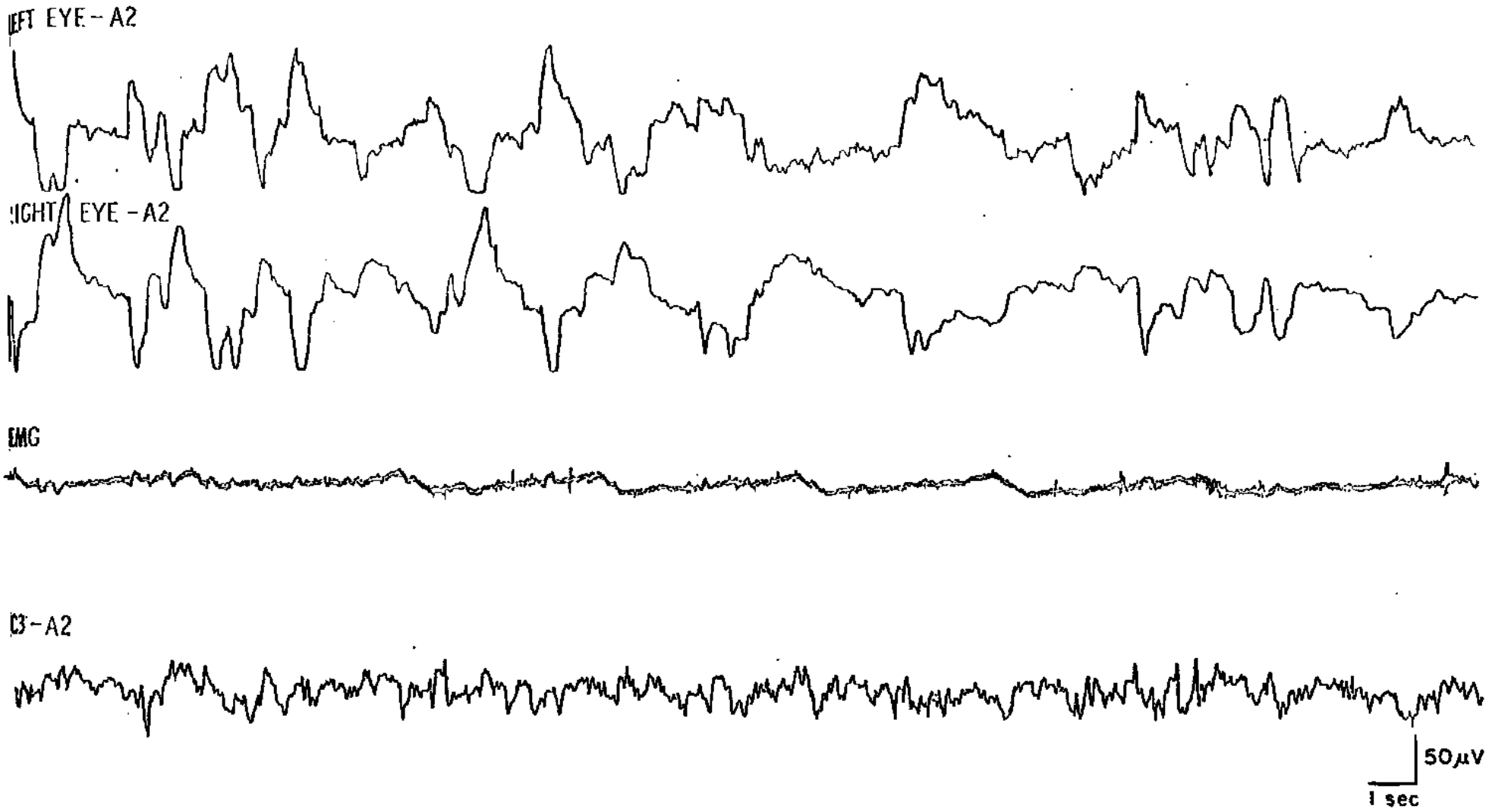


FIGURE 32

Stage REM. This is an unambiguous Stage REM. The fluctuations of the EMG baseline probably represent jaw movements associated with respiration.

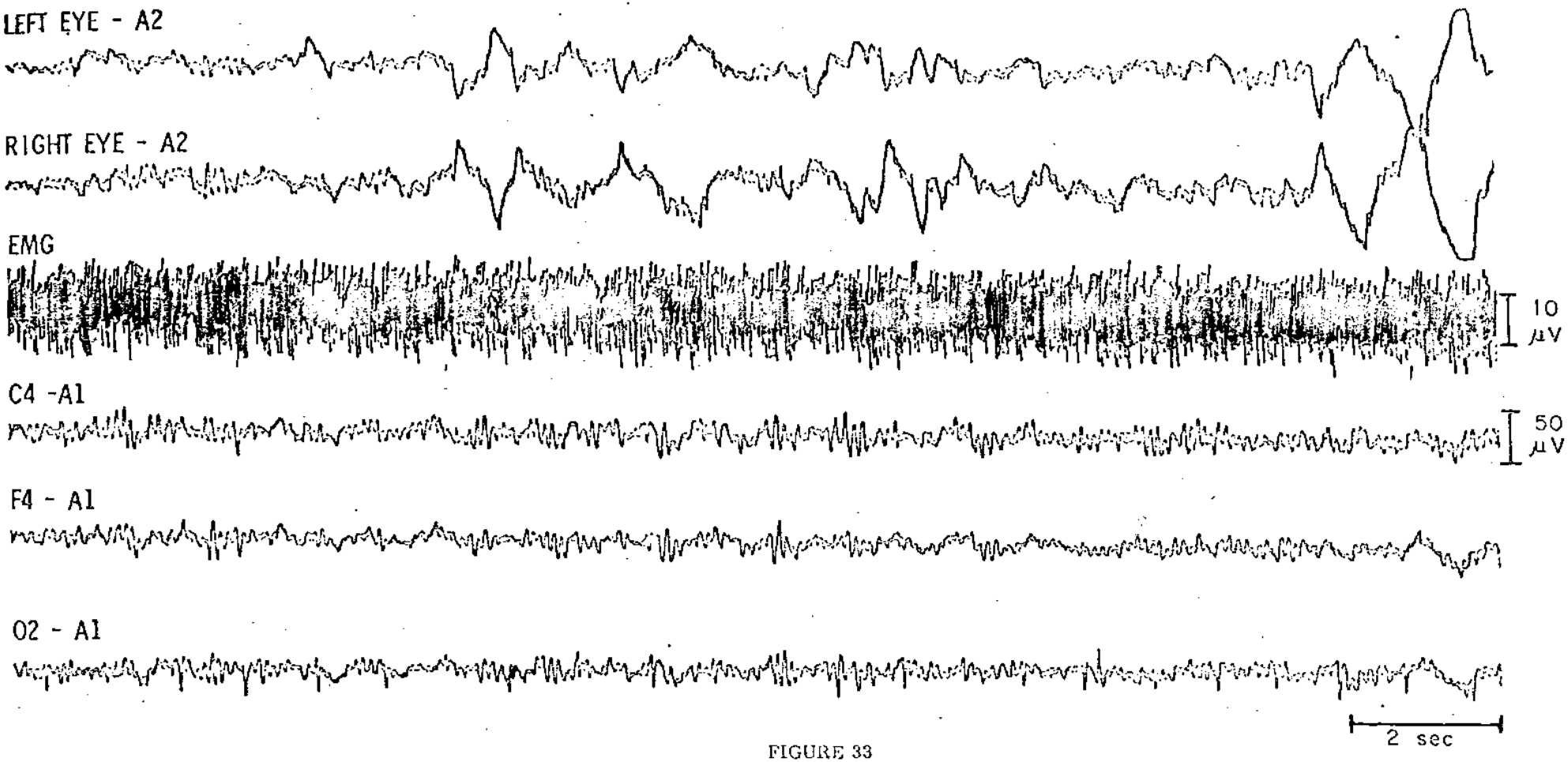


FIGURE 33

Stage W. This epoch illustrates an unambiguous Stage W. Note the REMs, high EMG and relatively continuous alpha activity.

FIGURES 33 - 40

Epochs from the various stages of subject 3 are presented. The subject was a 25 year old, normal, male college student. All the tracings are from the same night and were recorded on a Grass Model IV-C electroencephalograph. Each tracing represents a 20 sec epoch recorded at a paper speed of 15 mm/sec. For the eye movement and EEG channels the time constant was 0.3 sec; the calibration was 50 μV/cm. For the EMG channel, the time constant was 0.03 sec and the calibration was 10 μV/cm. A comparison may be made between the tracings from the Standard C4-A1 derivation which is used for scoring purposes and the F4-A1, O2-A1 derivations.

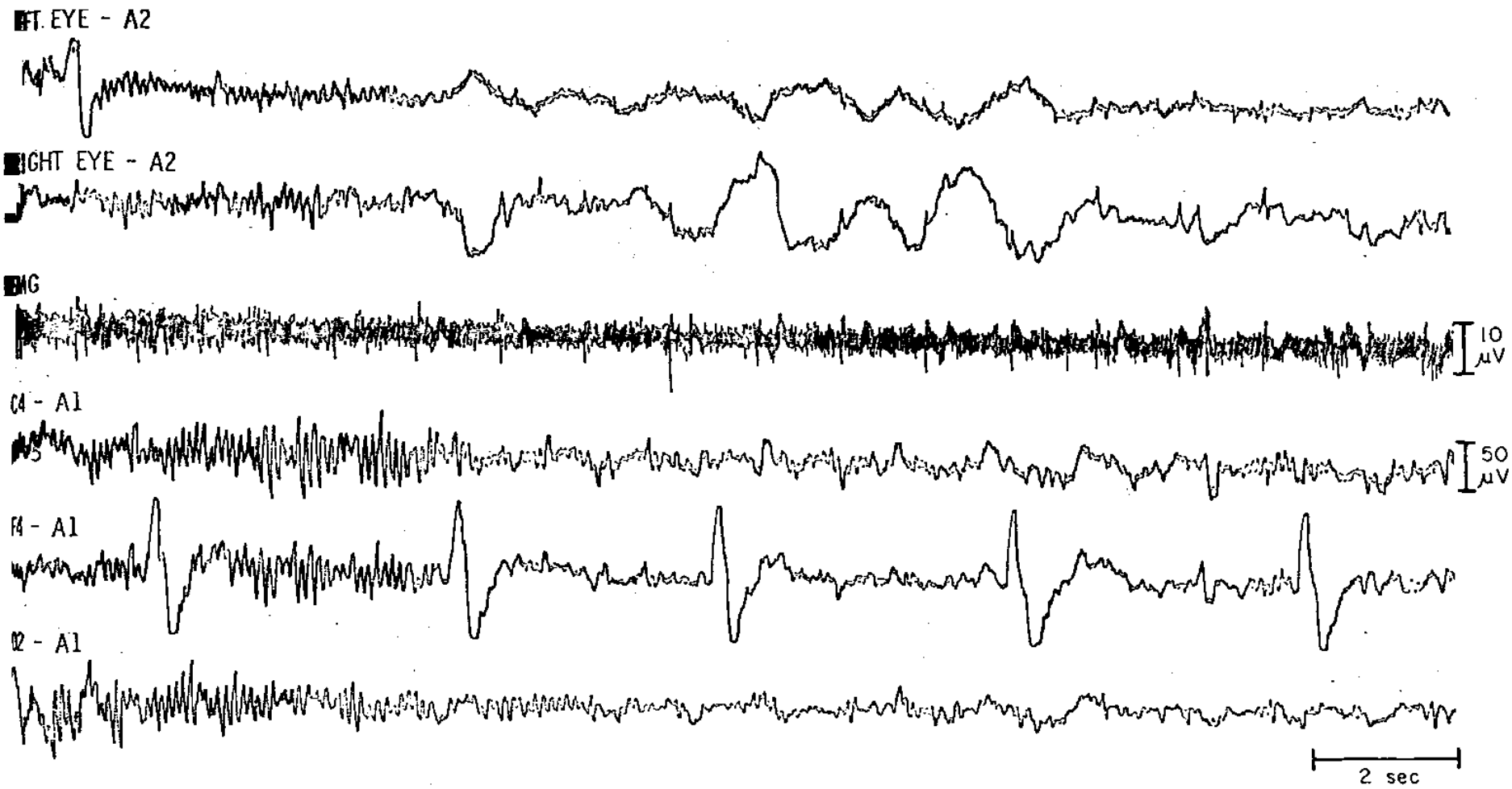


FIGURE 34

Stage 1. This epoch illustrates the transition from Stage W to Stage 1. ...de the continuous alpha at the beginning of the epoch, then slower fre-...encies appear with associated relatively low voltage activity. Slow eye movements are present and a high EMG is maintained throughout. A repetitive artifact is present in the F4-A1 derivation.

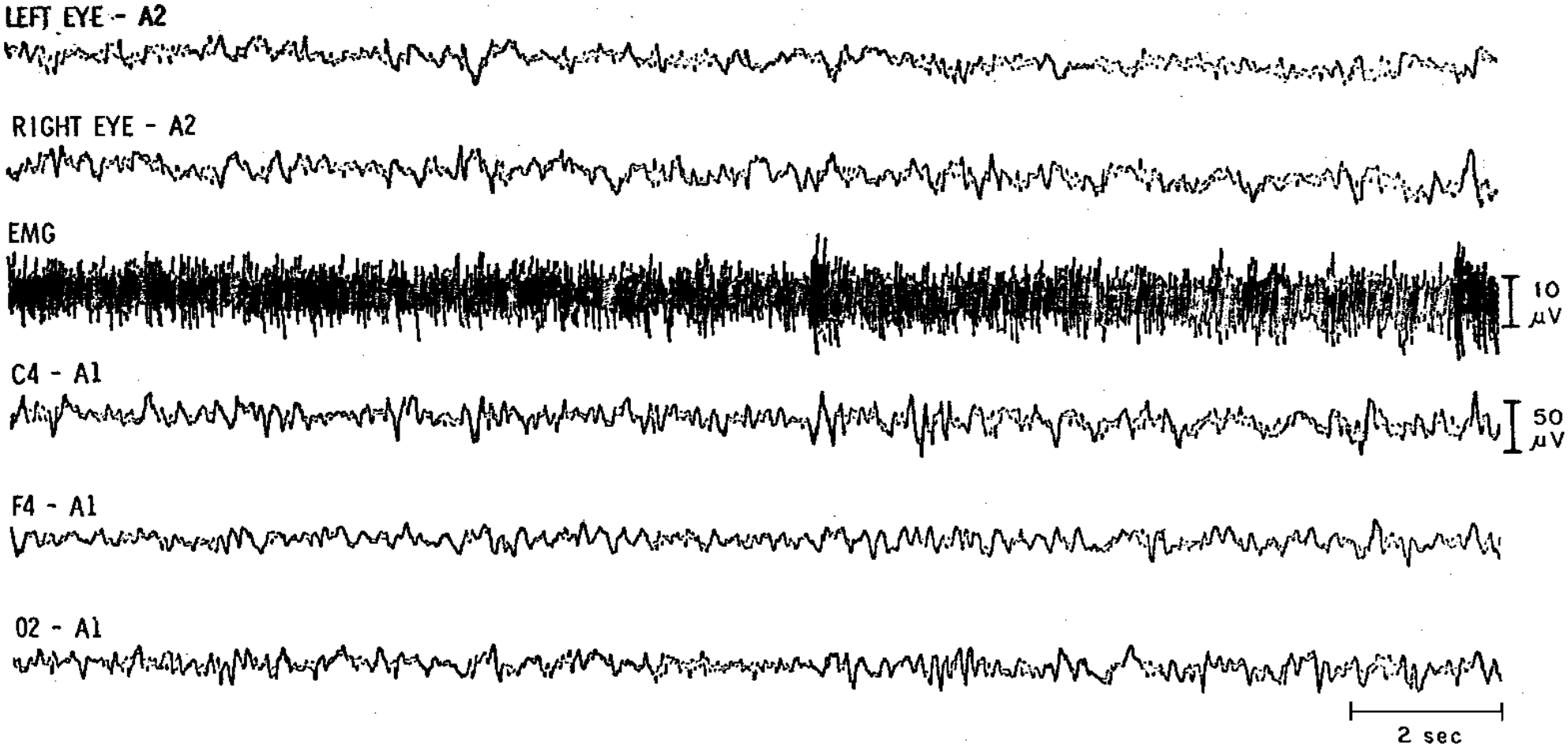


FIGURE 35

Stage 1. This epoch illustrates the later portion of Stage 1 with fewer slow eye movements and some vertex sharp waves in C4-A1.

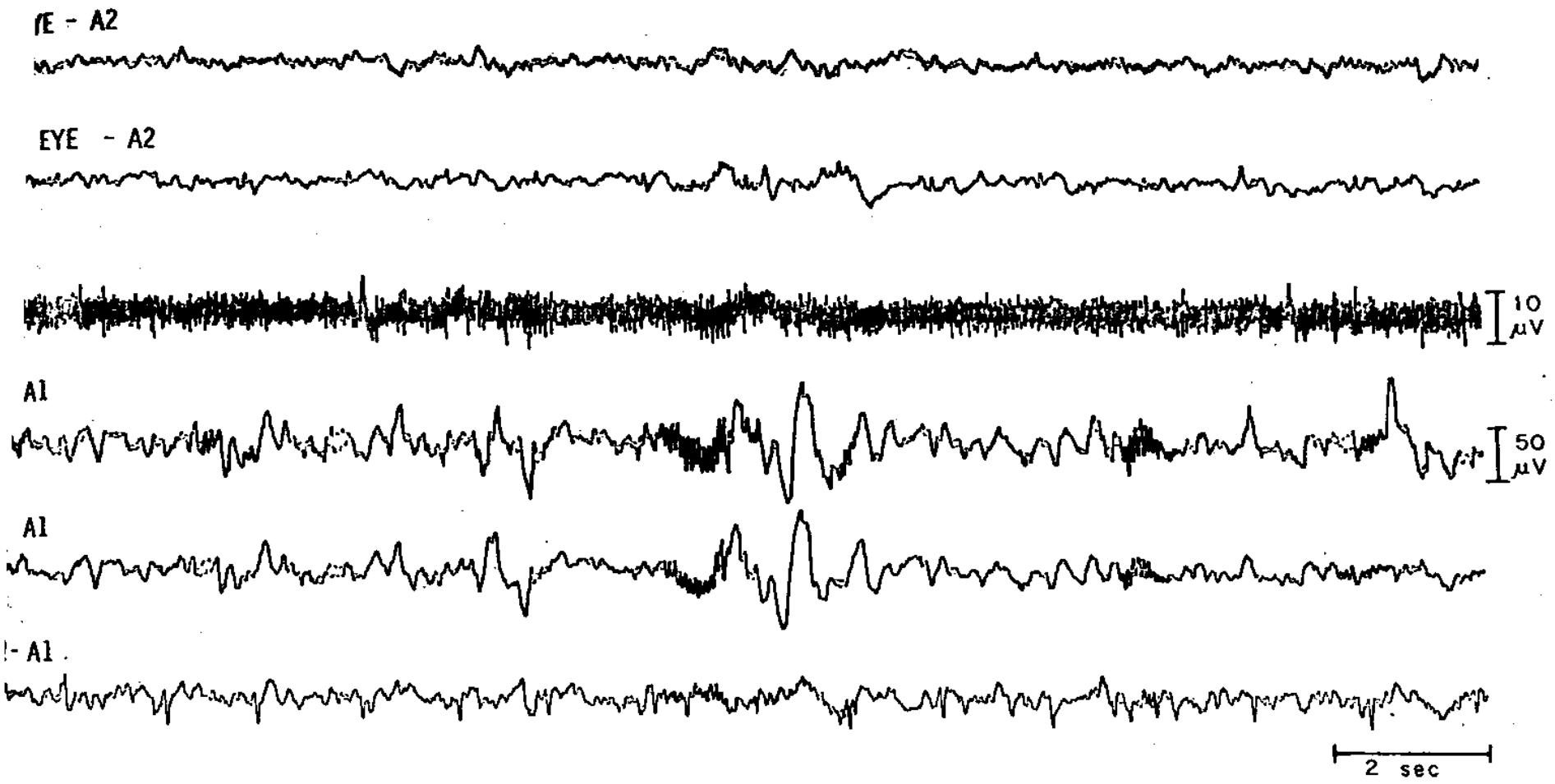


FIGURE 36

Stage 2. This epoch illustrates an unambiguous Stage 2.

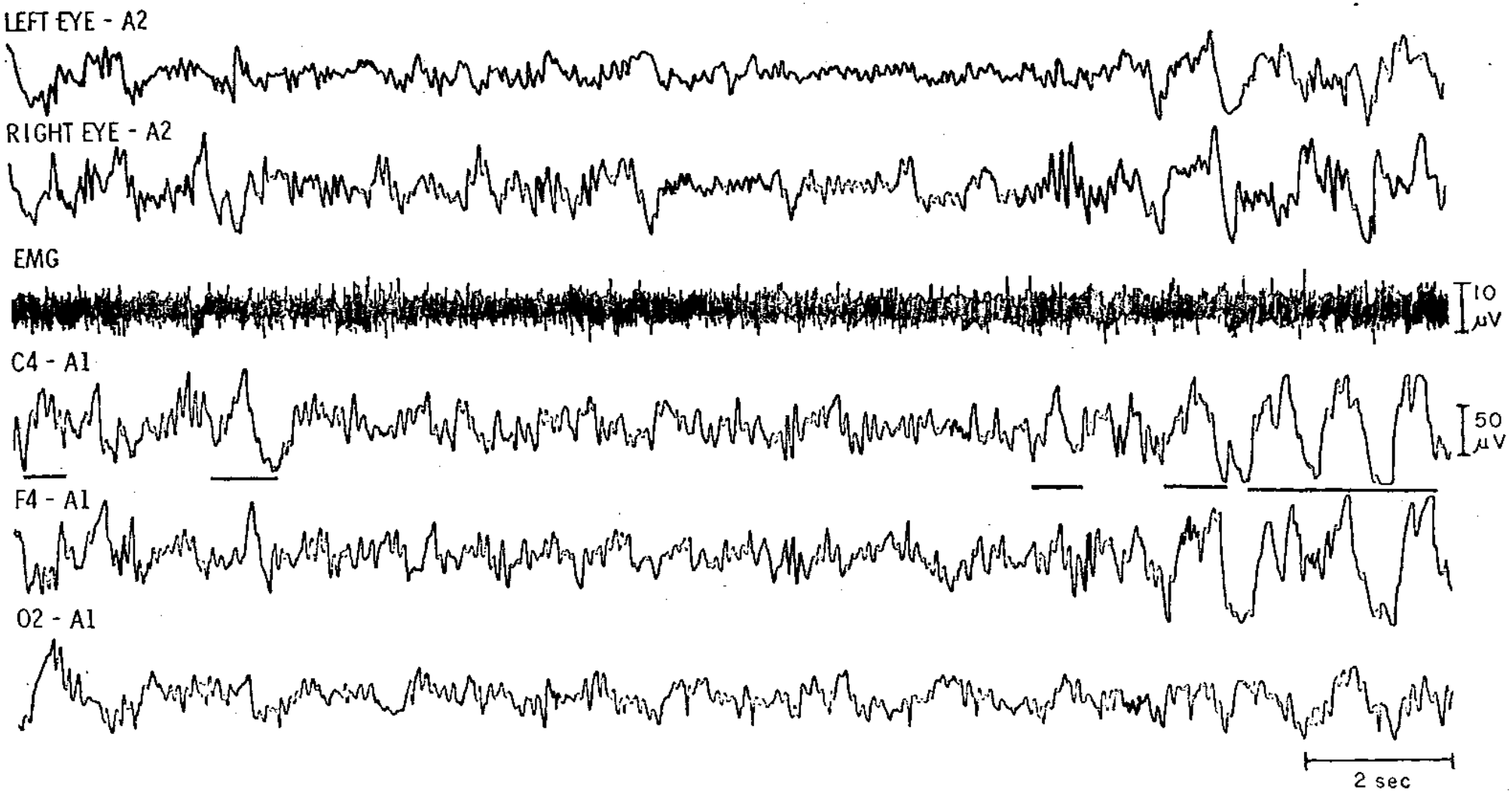
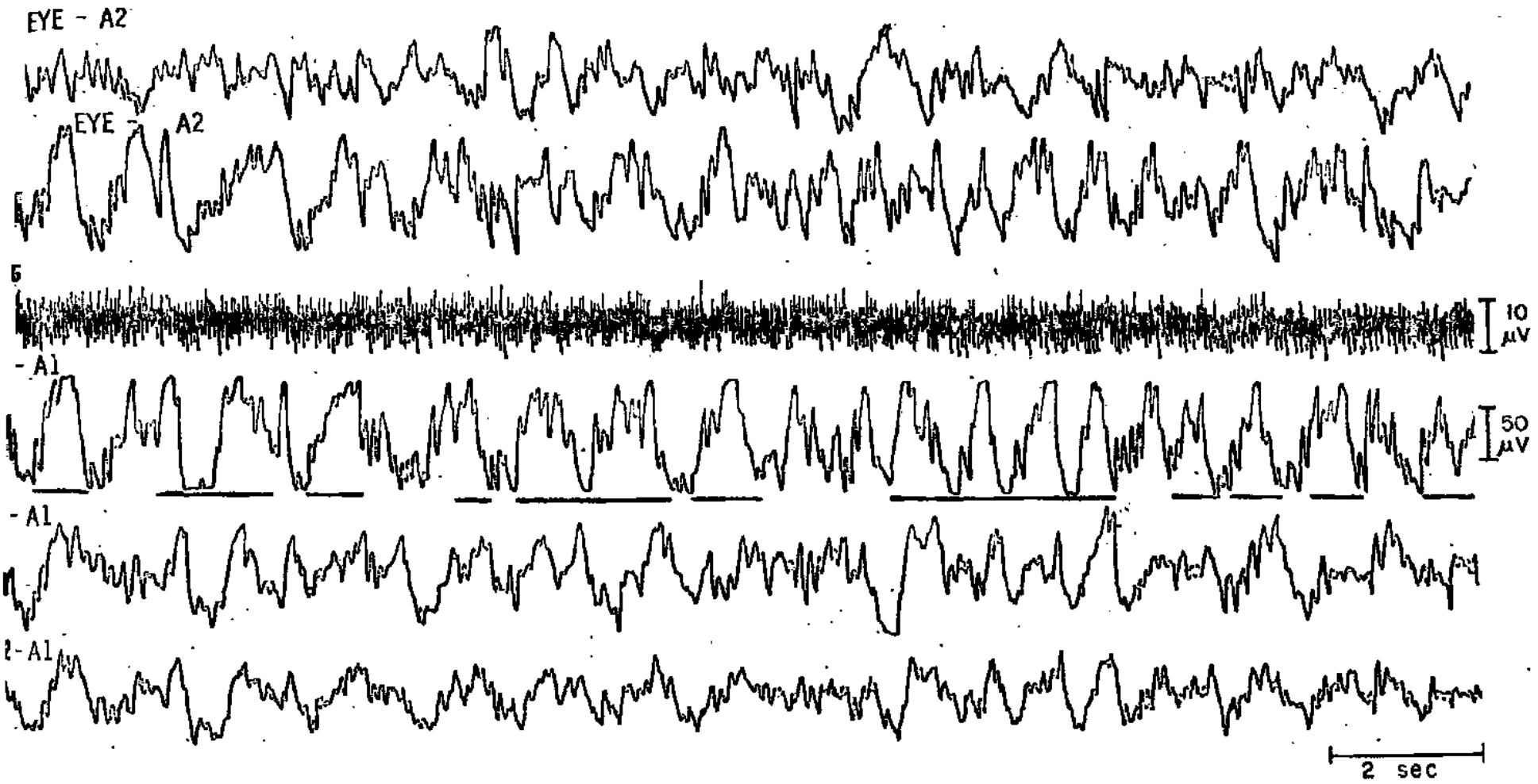


FIGURE 37

Stage 3. This epoch illustrates a Stage 3 record with approximately 28% acceptable, high amplitude, slow wave activity.



Stage 4. This epoch illustrates an unambiguous Stage 4.

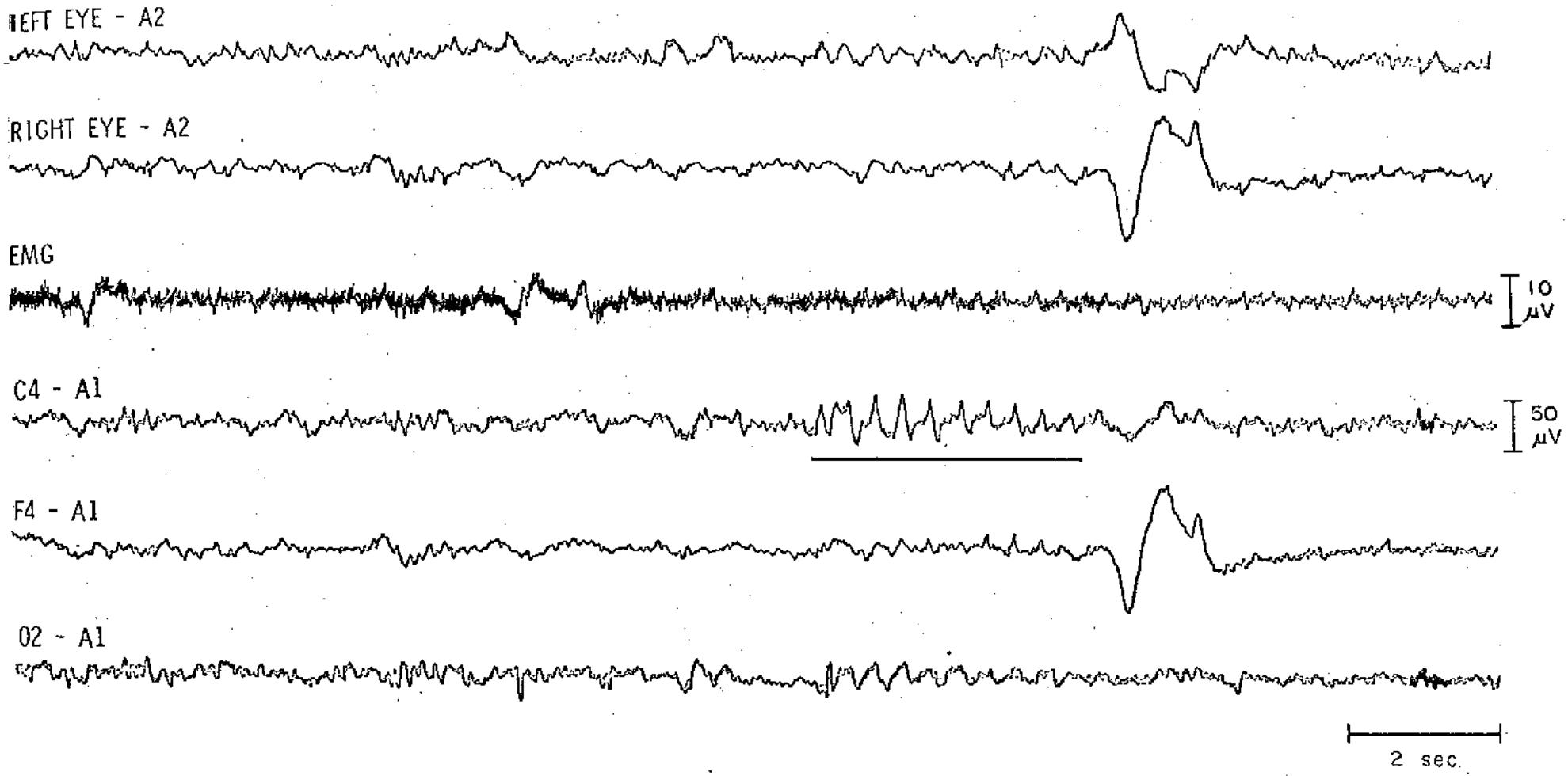


FIGURE 39

Stage REM. This epoch depicts the transition from Stage 2 to Stage REM with saw-tooth waves (underlined), REMs and decrease in tonic EMG. REMs are also recorded on F4-A1 derivation. (Sleep spindles were present just prior to this epoch.)